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HISTORY AND TREND OF THE TEACHING OF PHYSICS IN THE SECONDARY SCHOOLS OF THE UNITED STATES

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TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

Scientific inquiry can be traced to very remote times. Egypt used practical applications of physics as far back as 3700 B.C., as evidenced by their engineering skill in erecting the pyramids. The Babylonians made use of the lever and the pulley, lathes, picks, saws, and hammers. The present study will open with a brief discussion of the science of Athens and Alexandria. It was this period that gave to the world two men whose names have been associated with science ever since, namely, the great philosopher Aristotle whose theories were to have such a dominating influence in shaping the scientific thought of the world for the two thousand years following their propounding; and Archimedes who represented the first real proponent of experimental science.

The major portion of this study will be devoted to those changes that have occurred in physics teaching in the secondary schools of this country since the inception of the American Academy movement down to and including the present day. The writer has attempted to emphasize the forces in each period that have operated to place the teaching of physics in our secondary schools on such a basis that the subject might most

nearly fulfill the needs of the people according to the views of the day.

The science course constitutes one of the most important parts of the high school curriculum of today. As one of the major subjects of this course physics is to be regarded as a most desirable part of the education of every boy and girl who would make adjustments to life and society in the most efficient manner possible. Organizations of science teachers throughout the country are constantly at work attempting to determine the contents of the physics course, its relation to other subjects, and the most efficient methods of presentation. In no field of educational endeavor do we find more earnest or complete efforts to solve the problems that confront education than in that of physics. With this view of the vital importance of physics in the curriculum of the high school of today, this study of the history of the introduction and growth of physics has been made.

CHAPTER II

SCIENCE FROM THE DAYS OF ATHENS UNTIL THE SEVENTEENTH CENTURY

The history of any subject for a given period is always made more understandable if the development of the subject preceding that period is known. I shall therefore sketch very briefly the rise of scientific inquiry, beginning with the time when Athens was the intellectual capital of the Greek world.

Greek science in general rested on philosophic speculation rather than on observation, testing, and measuring. Socrates (470-399 B.C.), Plato (427-347 B.C.), and Aristotle (384-321 B.C.) were the greatest of the philosophers whose abstract thought has so greatly influenced the intellectual life of the world. The Athenian school curriculum included music, literature, religion, physical training, and citizenship, but did not include arithmetic, grammar, or science. Cubberley states, "Aristotle had done a notable work in organizing and codifying Greek scientific knowledge, ---but his writings were the result of keen observations and brilliant speculation, contained many inaccuracies and in time --- proved serious obstacles to real scientific progress."[1] Later, at Alexandria we find the Athenian method of speculation as to phenomena and causes still the vogue, al-

[1] Cubberley, Ellwood P. The History of Education, Page 381.

though we discover here our first real proponent of experimental science in "Archimedes (270?-212 B.C.), a pupil of Euclid's, who applied science in many ways and laid the foundations of dynamics."[2]

From the time of Alexandria until the middle of the 16th Century science, dominated by Aristotelian methods sanctified by a powerful religious atmosphere, was at a standstill. During these days of Rome and the middle ages we find, "Physics was often taught as a part of the instruction in astronomy, and consisted of lessons on the properties of matter and some of the simple principles of dynamics. Little else of what we to-day know as physics was then known."[3] C. R. Mann also describes the lack of advance in science during this period in his statement, "For these Middle-Age studies of physics consisted in memorizing Aristotle's speculations on this subject, and in having hair-splitting disputations as to their meanings and their possible implications."[4] It is true that Roger Bacon objected to Aristotelian methods as early as 1276 but his suggestions for something better fell upon deaf ears. Copernicus (1473-1543) can be regarded as the first modern scientific thinker, and "The beginnings of all modern scientific investigation date from 1543."[5]

From the time of the Italian, Galileo Galilei (1564-1642), the growth of physics has been continuous. He developed the

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[2] Cubberley, Ellwood P. The History of Education, Page 381.

[3] Ibid., Page 162.

[4] Mann, C. Riborg. The Teaching of Physics, Page 25.

[5] Cubberley, Ellwood P. The History of Education, Page 387.

telescope and by the use of careful scientific methods made numerous discoveries in physics. We are told that he "completely upset the teachings of the Aristotelians, and made the most notable advances in mechanics since the days of Archimedes."[6] The English scholar Newton (1642-1728) "made clear the nature of light; and reduced dynamics to a science"[7], while "The Englishman William Gilbert (1540-1603) --- laid the foundations of the modern study of electricity and magnetism."[8]

Thus we see the progress of science from the old scholastic deductive logic of Aristotle change to the basis of inductive reasoning of Francis Bacon - "the father of modern science." Cubberley writes of the latter group, "In time their work was destined to reach the schools, and to materially modify the character of all education."[9]

In the century following Copernicus the barometer, thermometer, air pump, pendulum clock had come into use; and modern ideas as to light and optics and gases and the theory of gravitation were about to be set forth. The tremendous interest in this new scientific work is seen by the numerous scientific societies that were organized during this period, including the Royal Society of London (1660); the Imperial Academy of Germany (1662); the Academy of Sciences in France (1666); and the National Observatory at Greenwich (1675). After 1650 the advance of science

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[6] Cubberley, Ellwood P. The History of Education, Page 388.

[7] Ibid., Page 388.

[8] Ibid., Page 389.

[9] Ibid., Page 390.

was rapid. During the reign of George I (1714-27) in England scientific work began to be popularized and the first little booklets on scientific subjects began to appear and were eagerly read. In 1704-10 the first "Dictionary of Arts and Sciences" was printed, and in 1688-71 the first edition of Encyclopedia Britannica appeared. 1755 saw the famous British Museum founded. In 1698 a rude form of steam engine was patented in England and James Watt in 1765 improved it so it was applicable to industry.

CHAPTER III

SEVENTEENTH AND EIGHTEENTH CENTURY SCIENCE

During the 17th and well into the 18th centuries, the extreme conservatism of the universities and their continued control by theological faculties found these institutions inhospitable toward the new scientific method, and practically all the leading workers were found outside the universities. Not until the close of the 18th century did the universities become sufficiently modernized to allow scientific workers to find in them an atmosphere conducive to scientific teaching and research, and they gradually became the homes of scientific progress and instruction. Science was studied and taught from a religious viewpoint. Natural Philosophy covered the whole realm of Nature, and all phenomena were explained as outward expressions of the mystical. Such a common fact as that air possesses weight was not known until 1643 when Torricelli made his crude barometer.

Charles Morton was a typical figure of science of this period. This scholar and preacher came from England in 1686 to teach science at Harvard College. To show how imaginative and speculative his teaching was, let us view his theory[1] on the

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1 Meriwether, Colyer. Our Colonial Curriculum. 1607-1776, Page 189.

migration of birds. Being skeptical of the prevailing theory that migratory birds hibernated at the bottom of rivers during the cold seasons, he built up the theory of their migration to the moon. He even calculated the time of their flight, figuring that they could travel at the rate of 125 miles an hour, 3000 a day, 180,000 in two months. A bird setting his gaze, by instinct, on the moon at a certain point in space, flew straight to that point and landed on the moon on its second trip around the earth. Two months going, four months on the moon, two months returning, allowed four months in New England.

Abraham Pierson, first president of Yale College, explained phenomena in his "Compendium Philosophiae Naturalis" from a religious angle. Gravesande and Rohault, science teachers at Yale, included in their teaching the subjects of physics, geography, astronomy, meterology and biology and taught them from a religious viewpoint. Meriwether writes, "Today science dominates our schools. Our colonial ancestors studied and taught in an atmosphere of religion which they had inherited from the middle ages. For centuries the pedagogic aim had been to point the road to Heaven."[2]

Even the "Laws" for 1642 had as their keynote "the main end of his [pupil] life and studies is to know God and Jesus Christ."[3] Experimentation did not constitute a prominent factor in our colonial college curriculum. Inventories of scientific apparatus at Harvard College covering the period 1731-1790 show

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2 Meriwether, Colyer. Our Colonial Curriculum. 1607-1776, Page 13.

3 Ibid., Page 53.

that only a few simple experiments were provided for, with no duplication of apparatus. Demonstration by the instructor was the only method used. An invoice of expenses for scientific apparatus at Harvard for the year 1740-41 shows a total expenditure for new apparatus and repairs of only £9.6s.10d. The meagre amount of demonstration also contributed its religious atmosphere as evidenced by the following quotation from a letter written by Mr. Thomas Hollis, of London, to Col. Hutchinson, Treasurer of Harvard, in connection with the shipping of a few pieces of apparatus, dated London, July 20th, 1732:

> "I hope Mr. Professor Greenwood will make good use of each, for the promoting useful knowledge and to the advancement of natural and revealed Religion."

Thus we find "Of the scientific attitude as it is cultivated today, of cold dispassionate study of nature without the lingering flavor of authority or of religion, our colonial ancestors knew nothing."[4]

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[4] Meriwether, Colyer. Our Colonial Curriculum. 1607-1776, Page 224.

CHAPTER IV

UNIVERSITY PHYSICS IN AMERICA

As was stated in chapter III, the sciences of chemistry and physics did not come into educational prominence until the latter part of the 18th century. Even as recently as 1830 we find "no college in America would have given chemistry an equal rank with Greek; today [1880] an election between the two subjects is in many of our best institutions freely permitted."[1] Before the Revolutionary War, natural philosophy was taught in American colleges, being subordinated to the study of mathematics. "Lectures were delivered upon mechanics, hydrostatics, pneumatics, and optics; a little was said about heat and sound; a few experiments in electricity were perhaps occasionally shown."[2] Experimental physics was yet in the first stages of development. The electric current was unknown; Rumford had not discovered the nature of heat; Oersted, Ampère, Davy, and Young were not even born, and Priestley, Cavendish, Scheele, Lavoisier, Dalton and Gay-Lussac had yet to make them-

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1 Report No. 6 1880 United States Bureau of Education. A Report on the Teaching of Chemistry and Physics in the United States, by Frank Wigglesworth Clarke, S.B., Professor of Chemistry and Physics in the University of Cincinnati, Page 380.

2 Ibid., Page 380.

selves famous by their discoveries. Oxygen was unknown. Physical laboratories and instruments of precision did not exist.

One by one the colleges adopted physics and chemistry. The University of Pennsylvania Medica School in 1768, Harvard in 1782, Dartmouth in 1798 recognized these sciences. William and Mary College had a Professor of chemistry and physics as early as 1774. The period 1800-1845 saw scientific studies grow more into favor. Technilogical schools were founded, the first being the Rensselaer Polytechnic Institute in 1824. During this period many illustrious men, such as Hare and Silliman, and Page and Henry were offering scientific discoveries to the world. Enthusiastic students were returning to our shores with the Old World laboratory methods. Between 1845 and 1850 scientific schools were established at Yale and Harvard; and the Smithsonian Institute and the American Association for the Advancement of Science were organized. Laboratory instruction in our universities obtained a strong foothold and rapidly grew in favor. The sciences were still taught from the utilitarian viewpoint however, and original research was lacking.

The year 1862 saw the greatest single step taken toward stimulating scientific education in our universities. Congress in that year passed an act granting to the several states large areas of public lands for the endowment of agricultural and mechanical colleges. New colleges were organized and old universities were strengthened. The Massachusetts Institute of Technology was founded and the Sheffield Scientific School was improved. These are typical cases. In every state scientific education secured a firmer foothold. Professor Clarke states

the situation in 1880 to be "Today the higher chemistry can be studied in a score of places where twenty years ago no adequate facilities were offered, and the modern physics, with its mathematical methods and its laboratories, is rapidly coming into vogue."[3]

One feature of this spread of scientific teaching was its influence on the secondary schools. They too were organizing laboratories and teaching their students to experiment for themselves, thus preparing them for higher work, until we find in 1880, "Today chemistry and physics are taught in nearly all the academies and high schools of the land; so that the larger colleges, whenever they see fit, may easily require from the candidates for admission a wider knowledge of these sciences than they themselves taught a dozen years ago."[4]

A second important feature of this university development of physics was that it was gradually evolving a body of subject matter which could be transferred, with certain modifications, to the lower schools.

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3 Report No. 6 1880 United States Bureau of Education. A Report on the Teaching of Chemistry and Physics in the United States, by Frank Wigglesworth Clarke, S.B., Professor of Chemistry and Physics in the University of Cincinnati, Page 382.

4 Ibid., Page 383.

CHAPTER V

NATURAL PHILOSOPHY IN THE AMERICAN ACADEMY AND EARLY HIGH SCHOOL

The first half of the 19th century continued the breaking away from the theological interpretation of natural phenomena. The great investigators already mentioned and many others including Ohm (1787-1854), Helmholtz (1821-1894), Volta (1745-1827), Daniell (1790-1845), and Faraday (1791-1867) were active in research. The steamboat and locomotive and various other mechanical inventions were gradually awakening the people of all civilized countries to the utilitarian view of science. Europe had already recognized this in her education by the establishment of the scientific secondary school (Realschule) in Germany in the 18th century.

School physics is not so old as University physics. There is a record of its having been taught in the academy at Northampton, England, as early as 1729.[1] No natural science was found in the Colonial grammar school. With the establishing of secondary education in the United States during the latter half of the 18th century and the first

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[1] Brown, E. E. The Making of Our Middle Schools, Page 171.

half of the 19th it was only natural to include science in its curriculum. "In America, Natural Philosophy was one of the subjects studied in the academies from their very beginning. In 1754, we find Rev. Wm. Smith teaching 'natural and moral philosophy' at the 'Publick Academy in the City of Philadelphia', the one founded under the influence of Benjamin Franklin."[2] Likewise it appeared in the courses of study in the first public high schools in New York in 1825. Clinton Academy was incorporated in 1787 and had twelve scholars in Natural Philosophy in its first class. However, up to the early part of the 19th century science had as yet formed no conspicuous part of the secondary school curriculum.

Numerous textbooks on natural philosophy were published during the 18th century, one of the most successful being James Ferguson's, published in 1750. This text was revised in 1805 by Sir David Brewster and brought out in America in 1806 by Robert Patterson, Professor of Natural Philosophy in the University of Pennsylvania.

The early introduction of natural philosophy into the academy program of studies indicates that the purpose for which it was intended was quite different from that which supplied the motive for university physics. The academies were founded in order that the pupils might learn "those things that are likely to be most useful and most ornamental, regard being had to the several professions for which they were intended."[3] Thus it is evident that this period regarded natural philosophy as one well calculated to meet the needs of the people. Also since it did not receive

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[2] Mann, C. R. The Teaching of Physics, Page 29.

[3] Brown, E. E. The Making of Our Middle Schools, Page 180.

credit for college entrance until 1872, its instruction evidently did not meet the college ideas of education. The Phillips Andover Academy is typical of the secondary schools of this period and it was founded "for the purposes of instructing Youth, not only in English and Latin Grammar, Writing, Arithmetic, and those Sciences wherein they are commonly taught; but more especially to learn them the Great End and Real Business of Living ---." They still retained the Latin of the Latin Grammar School but made most of new subjects of more practical value.

Especially interesting are Brewster's comments[4] on Ferguson's text. He says, "The chief object of Mr. Ferguson's labors was to give a familiar view of physical science and to render it accessible to those who are not accustomed to mathematical investigation," and, "Mr. Ferguson may be regarded as the first elementary writer on natural philosophy, and to his labors we must attribute that general diffusion of scientific knowledge among the practical mechanics of this country ---." And again, "No book upon the same subject has been so generally read, and so widely circulated, among all ranks of the community. We perceive it in the workshops of every mechanic. We find it transferred into the different encyclopedias which this country has produced, and we may easily trace it in those popular systems of philosophy which have lately appeared." We can easily understand the popularity of Ferguson's book in a period (1750-1825) when machinery was being rapidly introduced into all branches of industry. Sixty-two pages were devoted to machines, and forty pages to pumps. There was a large and constantly increas-

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[4] Woodhull, J. F. The Teaching of Physical Science. Teachers College Record. Vol. XI. 1910. Page 18.

ing demand for scientific knowledge by the public and education invoked natural philosophy and other sciences to meet the need and supply the demand.

It is evident that secondary school physics did not begin as a phase of university physics with its mathematical basis but rather as a felt need on the part of the public for a proper understanding of the rapidly advancing scientific era.

Natural Philosophy was part of the curriculum of the first public high school, the English High in Boston, from the start in 1821. Brown writes that these public schools were established because "no one of the colleges fully answered the public need as regards higher education"[5], and because "the commercial activities of the larger towns called for a different kind of training from that offered by the schools designed to prepare for college."[6] The English High represents what was done in natural philosophy in the secondary schools of the United States up to the middle of the 19th century. In 1823 an appropriation of $2,500. for the purchase of scientific apparatus was made. We find "No actual laboratory work was done by pupils until much later. This early physics teaching was much more satisfactory from the viewpoint of the subject matter, than from that of the teaching method. Recitations were usually formal, individual and dependent upon the text, as distinguished from the more natural, social, experimental and demonstration types of today."[7]

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[5] Brown, E. E. The Making of Our Middle Schools, Page 280.

[6] Ibid., Page 295.

[7] Rusk, R. D. How to Teach Physics, Page 26.

CHAPTER VI

INDUSTRIAL AND SCIENTIFIC MOVEMENT IN EUROPE AND ITS SPREAD TO AMERICA

About the middle of the 19th century we find Europe in the throes of a general industrial, scientific, and technical educational movement. Special schools were turning out not only scientists, but also men trained for the trades. The educational statistics for 1856-7, as reported in Barnard's Journal of Education, show the following facts regarding this scientific training in Europe:

Prussia had seventy-one realschulen with 20,931 pupils. At the Rendsburg realschule natural science was taught in all six classes. The capital of Hanover had one realschule and twenty-five science teachers in the gymnasia. In Saxony were found three or four realschulen. In Planen and Zittan parallel classes were joined to the gymnasium in which Natural Philosophy was taught two hours a week in the second and third classes. Saxony's Royal Industrial School at Chemintz offered Natural Philosophy four hours a week in the fourth class; Mechanics five hours in the third class; Mechanical Physics six hours in the first or highest class. Austria had one realschule at Pesth. Bavaria had five realschulen, and Baden had

1872 students in realschulen.

This great industrial movement of Europe naturally spread its influence to America, and as already stated, it was during this period that Yale and Harvard established their scientific schools, and that various scientific societies were founded.

The high school also felt the effects of this movement. A new science sprang up as a result. Natural Philosophy from the inception of the academy movement had been satisfied with teaching a few elementary facts, observational and theoretical, concerning the most common natural phenomena. The new era demanded a science that would make its learners more proficient in the arts and trades.

The state of science teaching previous to this time is illustrated in an article by A. Diesterweg.[1] He tries to answer the questions: Should Natural Philosophy be studied in common schools? What should it begin with? When should it begin? What portions should be stressed? What method should be used? What is its aim? He concludes that Natural Philosophy should of course be taught in the common schools, and should start at an early period. The method should be inductive, taking observations of single facts of common knowledge to be used as the basis for reflection, followed by abstracting the laws of the process, and then in inverse order, deducing the phenomena from the causes. The aim was a knowledge of the most common phenomena and ability to explain them. To show what Diesterweg be-

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1 Barnard's American Journal of Education. Vol. 4. Catechism on Methods of Teaching, translated from Diesterweg's "Almanac" (Jahrbuch) for 1855-6, by Dr. Herman Wimmer, PP 242-3.

lieved should be stressed, he says, "Shall the children in the common school learn nothing of weather and wind, of thermometer and barometer, of the phenomena of light and air, of rain and snow, dew and hoar, frost, fogs and clouds, lightning and thunder? Shall they see the aërnaut, travel by steam, and read telegraphic news, without knowing the how and the why? Shall they remain ignorant of the constituents of food, and of the process of their stomachs and their lungs?"

It is to be noted from Diesterweg's conclusions that natural philosophy up to this time consisted of a smattering of everything in the realm of nature, thus giving a superficial knowledge of a wide range of more or less related facts, without a scientific study of any particular field. Furthermore, the Athenian method of observing and reflecting to arrive at knowledge still persisted with no mention made of experimental methods.

In the year 1855, Daniel C. Gilman was pointing out to the American people the tremendous success of the European scientific schools, and urging improvement of our science instruction. The next year James D. Dana, in an address[2] before the Alumni of Yale College, urged Yale to take the lead in America in this new science movement. American producers were learning that to compete with European manufacturers our schools must unite the theoretical and applied science that was evolving in leaps and bounds.

So we can look upon the middle of the 19th century as being the starting of the transition from the old to the new science -

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[2] Barnard's American Journal of Education. Vol. II. PP 349-374.

the first, called Natural Philosophy, which covered the whole realm of nature from a theoretical viewpoint; and the latter called Physics, with its narrowed field and its more intensive study to the industrial applications of its theoretical observations and reflections.

We find the new utilitarian motive in secondary school science emphasized in the first St. Louis high school, organized in 1853. This school adopted two courses, a classical and a general course. The first provided those studies necessary for admission to the best American colleges. The second included in addition to a certain amount of classical studies, "such studies in science and literature as shall best fit pupils for different departments of business, and make them generally intelligent." The program of 1863 required a half year of Natural Philosophy in the second year. Chicago in 1866 gave a full year of Natural Philosophy in the third year of the course in the general department of its high school.

Practically all the high schools of the country had at this time only classical and English departments. Extracts[3] of the official returns from thirty cities of the United States for this period show that natural philosophy was taught in the high schools of all these cities. But, although it was gradually being included in the program of studies of the high schools throughout the country, natural philosophy was not destined to play a conspicuous role in the high school courses for some years to come. Perhaps the greatest obstacle to the introduction of the new science into the curriculum was the lack of a method of teaching science

[3] Barnard's American Journal of Education. Vol. 19. Page 463.

that would make the subject a real one to the pupil. So long as a pupil was forced to learn science from a book with the small amount of experimentation performed by the teacher - so long would the general introduction of science be retarded.

CHAPTER VII

INTRODUCTION OF LABORATORY WORK

Until Galileo's time experimentation was unheard of. Hard thinking on observed phenomena was considered the sole requirement for scientific advancement. To many people experiments were looked upon as dangerous to both intellectual and moral life. Even as late as 1856 we find James D. Dana utter such statements as "It is painful to witness the dread of this science [of nature] that is so often displayed --"[1] and "Yet there are many who still look with distrustful eyes on science"[2]. This scholar gives a more hopeful view of the near future by claiming that science is gradually gaining ground as not being the monster of atheism so long regarded as, and by saying, "We have reason for gratulation, that our country is beginning to appreciate the importance of scientific culture."[3]

1 Barnard's Journal of American Education. Vol. 2. Page 364. Science and Scientific Schools. James D. Dana.

2 Ibid., Page 350.

3 Ibid., Page 365.

Experimental work in the secondary schools was to be found even as early as the first part of the 19th century. Woodhull says, "Previous to 1870 there was much in the way of 'Philosophical apparatus' in the schools ---" and "As early as 1837 the city of Boston furnished each of its grammar schools with a set of physical apparatus costing $275. for each set. A similar set was to be found in most of the academies of the country about that time ---."[4] But the apparatus was for use of the instructor only.

High schools throughout the country during the third quarter of the century began to introduce Physics and Chemistry as distinct subjects, and the elective method, which was gradually being adopted, especially in the West, rendered their introduction possible in many schools where they had not before been recognized. Physics was usually an elective subject but occasionally was included in the prescribed "core." However, as an elective subject, Physics could not be expected to be generally elected until the method of teaching it proved more interesting and useful than in the past. Lack of contact between pupil and subject matter was the fault. The recognition of this fault had been steadily growing, and beginning about 1870 and for a period of about ten years following, there was much discussion of method, and a strong plea for individual laboratory work by the pupil. To quote Woodhull again, "Between 1870 and 1880 much was said about the value of individual laboratory work and the use of the inductive method."[5] But even the close of this decade which was

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[4] Woodhull, John F. The Teaching of Physical Science. Teachers College Record, Vol. XI, 1910. Page 6.

[5] Ibid., Page 6.

marked by such vigorous agitation for individual work and the inductive method did not actually see many schools which had adopted the laboratory method. Yet the few which were taking the step were to prove the vanguard of a movement that was to grow to the complete exclusion of the old book-method.

It was a period of much bewilderment. Some teachers thought that individual laboratory work was impractical. The expense involved and the difficulty of securing trained teachers were the two greatest obstacles to the general introduction of individual laboratory work. This movement for laboratory work and the inductive method served as a powerful factor in establishing greater interest in physics teaching, and it began to receive a distinctive place in the high school program. More and more schools were including it in their curriculum.

Of great assistance to the introduction of the laboratory method were the textbook writers of the first part of the last quarter of the 19th century. Practically every book emphasized the value of individual laboratory work and the inductive method in making knowledge real. It was generally thought that the study of physics ought to train pupils to think, and to give them ability to solve problems in any field of endeavor. Laboratory work and the inductive method were both supposed to be especially efficacious in producing mental discipline.

Reference[6] to the prefaces of a few typical textbooks of this period will show how vitally important these two phases of science instruction were becoming. From 1873-78 Steele wrote in his prefaces to books on chemistry and physics, "As far as possible every question and principle should be submitted to

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[6] Woodhull, John F. (ante, footnote p.23).

nature for a direct answer by means of an experiment." In 1872 Eliot and Storer wrote in their Elementary Manual of Chemistry, "The authors' object is to facilitate the teaching of chemistry by the experimental and inductive method, to develop and discipline the observing faculties". In Avery's Chemistry (1881) we read, "As far as possible the experiments are to be performed by the pupil rather than for him." Gage's Physics had stamped upon the cover "Read nature in the language of experiment", and in the preface we find, "So far as practical, experiments precede the statements of definitions and laws, and the latter are not given, until the pupil is prepared, by previous observation and discussion, to frame them for himself."

CHAPTER VIII

THE STATUS OF PHYSICS INSTRUCTION IN 1880

A wealth of material picturing the conditions of physics teaching during the decade preceding 1878 is contained in the United States Bureau of Education Report No. 6 1880. Since this Report is of such an authoritative nature and covers the subject of physics teaching for this period so thoroughly I shall dwell at considerable length on it, hoping that by doing so the reader may obtain a clearer view of this transition period of physics from a book subject to an experimental subject, and therefore have a clearer appreciation of the changes in the next few decades as described in succeeding chapters.

Towards the close of the year 1878, the United States Commissioner of Education sent out a circular containing comprehensive questions relative to the teaching of chemistry and physics in the United States. The history of instruction, present courses, textbooks used, value of apparatus, laboratory facilities and policy, and other topics were all made subjects of inquiry. Later a supplementary circular was issued covering

the same ground but especially addressed to Superintendents of public schools in the larger towns and cities. More than six hundred schools answered the questionnaires. Professor Frank W. Clarke, of the University of Cincinnati, analyzed the voluminous material thus collected and made a thorough report. He states, "the purpose of the report is two-fold; first, to state the facts, and, secondly, to point out defects and remedies."[1] The collected data show that there are two schools of scientific teachers - one believing that a full course of didactic instruction should precede the admission of students to the laboratory; and the other insisting that laboratory and classroom work should go side by side from the beginning. Professor Clarke takes a decided stand with the latter group, emphasizing that the aims of sciences are "not only to give mental discipline, but also to train the faculty of observation and to teach the scholar the experimental method of grappling with unsolved problems".[2] Two major difficulties stand in the way of the general introduction of laboratories: first "the difficulty of finding trained teachers or teachers with whom science was not subordinate to other things; the second arises from consideration of expense".[3] Professor Clarke shows that whereas the first is real enough, it is rapidly dying out; and the second has no real foundation. He also deprecates the lack of coöperation between the secondary schools and the colleges, stating that "in most cases the latter

1 Report No. 6 1880 U. S. Bureau of Education (ante, footnote p.10), Page 377.

2 Ibid., Page 378.

3 Ibid., Page 379.

teach chemistry and physics to the same extent as the former and in essentially the same way"[4]. He recommends that the preparatory schools advance the study of science to the latter years of the program, while the colleges offer it earlier in their program so as to give direct progression.

The reports received from schools throughout the country indicate the following general facts[5] regarding the sciences in the secondary schools:

first: "instruction in chemistry and physics is very generally given".

second: "in the great majority of cases mere textbook work is done, only a few experiments being performed by the teacher." In a few cases laboratory practice is had in both chemistry and physics.

third: It is generally admitted that chemistry and physics are desirable branches to teach in secondary schools.

fourth: "It may be safe to put half an academic year as the minimum time assignable to either subject. A year can usually be given to each without difficulty."

fifth: "instruction should be general rather than specific".

sixth: "No textbook can be taken as sole guide and followed without variation; but a good treatise --- may be of great help to both teacher and pupils."

seventh: "In the recitation or lecture, general principles are taught; in the laboratory the student becomes familiar with methods and details."

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4 Report No. 6 1880 U. S. Bureau of Education (ante, footnote p.10), Page 379.

5 Ibid., PP 383-7.

eighth: laboratory work "should coincide with the classroom instruction and divide the time at least evenly with the latter".

ninth: "every year the number of teachers competent to give laboratory instruction is greatly increased, and before long the supply will be equal to any demand which is likely to arise."

Regarding the Normal Schools, which were at this time of secondary school grade, Professor Clarke says, "By far the greater number of them treat these sciences exactly as they are treated in secondary institutions and the smaller colleges; that is, they teach the elements of both subjects, partly by textbooks and partly by lectures; a few experiments are exhibited, and laboratory work on the part of the students is entirely ignored."[6]

In the table below are two colums, A and B, containing data derived from the Report. Column A gives by decades the number of schools introducing physics into the curriculum as reported by one hundred and thirty-three public schools in cities of 7,500 population or greater. Table B gives the same data as reported by two hundred and twenty-one secondary schools, excluding those listed in A but including small public schools, and private schools and academies.

Number of Secondary Schools Introducing Physics into the Curriculum

Decade	Column A	Column B
1790-1800	0	1
1801-1810	0	0
1811-1820	0	6
1821-1830	4	9
1831-1840	1	13
1841-1850	12	25
1851-1860	42	43
1861-1870	45	66
1871-1878	29	58

6 Report No. 6 1880 U. S. Bureau of Education (ante, footnote p.10), Page 395.

It will be noticed that from the earliest date reported, 1790, up to and including 1850, physics instruction was reported in 71 schools. In the next three decades physics was introduced into 85, 111, and 87 schools respectively. It must be remembered that this marked increase in physics instruction was not due entirely to increased interest in this subject since this was the period of general secondary school growth in which many new schools were organized due to the demands of increased population. It is reasonable to believe however that the introduction of physics into the course of instruction exceeded the organization of new schools, for Inglis writes, "interest in the study of the natural sciences developed faster than the public high school".[7]

Regarding textbooks the report shows that whereas there were 53 general texts on physics and 56 additional texts on the several units in physics on the market, the large public schools reporting practically limited their choice to the following ten general textbooks:

36	schools	used	Steele, J.D.	Fourteen Weeks in Natural Philosophy
29	"	"	Norton, S.A.	Elements of Natural Philosophy
20	"	"	Cooley, LeRoy C.	Natural Philosophy
16	"	"	Norton, S.A.	Elements of Physics
15	"	"	Rolfe, W.J. and Gillet, J.A.	Natural Philosophy for High Schools and Academies
15	"	"	Quackenbos, G.P.	Natural Philosophy
10	"	"	Steele, J.D.	Fourteen Weeks in Physics
9	"	"	Avery, E.M.	Elements of Natural Philosophy
6	"	"	Peck, W.G.	Introductory Course of Natural Philosophy
5	"	"	Wells, D.A.	Natural Philosophy

The small public schools, and private schools and academies reporting practically limited their choice to the following

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[7] Inglis, A. Principles of Secondary Education, Page 507.

fourteen textbooks:

119	schools used	Steele, J.D.	Fourteen Weeks in Natural Philosophy
70	" "	Quackenbos, G.P.	Natural Philosophy
41	" "	Peck, W.G.	Introductory Course of Natural Philosophy
37	" "	Wells, D.A.	Natural Philosophy
27	" "	Avery, E.M.	Elements of Natural Philosophy
23	" "	Norton, S.A.	Elements of Natural Philosophy
20	" "	Cooley, LeRoy C.	Natural Philosophy
18	" "	Rolfe and Gillet	Natural Philosophy for High Schools and Academies
13	" "	Norton, S.A.	Elements of Physics
10	" "	Ganot, A.	Elementary Treatise on Physics, Experimental and Applied, trans. and edited by E. Atkinson
10	" "	Stewart, Balfour	Primer of Physics
7	" "	" "	Lessons in Elementary Physics
7	" "	Olmsted, D.	Introduction to Natural Philosophy, revised by E. S. Snell (larger work)
6	" "	Ganot, A.	Natural Philosophy for general readers and young persons, trans. by E. Atkinson

The cost of apparatus for chemistry and physics as reported by the different schools varied from nothing to as high as six thousand dollars, the average being less than five hundred. However, cost of apparatus must not be taken as a fair estimate of the quality of science instruction, since a hundred dollars spent on simple, fundamental pieces would aid teaching more than a thousand dollars spent on elaborate toy-type pieces. Again, many instructors used school-made apparatus quite effectively at an insignificant cost. It is interesting to note that in connection with the cost of apparatus Congress a few years earlier had passed a law admitting foreign made apparatus for schools duty-free.

The instructor of physics also usually taught chemistry and other subjects.

There seemed to be no uniform grade for the study of physics,

it ranging from the first to the last year of the secondary course, with the majority giving it in the sophomore or junior years.

Three typical courses were offered:

"Elementary oral instruction, with experiments by the teacher."

"Elementary textbook work, without experiments."

"Course in elementary physics with class experiments but no laboratory work."

The number of exercises per week devoted to physics varied in the main between three and five, the average falling between four and five. The length of the course also varied, with approximately equal numbers of schools offering respectively a full year course, a two-third year course, and a half year course.

The most significant features of this report are: first, the great lack of uniformity in the teaching of physics in schools of a similar grade throughout the country; and second, the slight coördination between the work in colleges and in preparatory schools.

In order to gather facts for the placing of physics teaching on a more uniform basis, in the fall of 1883 the Commissioner of Education of the United States sent out another circular to secondary schools, normal schools, and colleges about the teaching of physics, and seventy replies were received. The purpose of the circular in brief was "for the purpose of showing <u>how</u> they [natural sciences] should be taught and <u>what</u> <u>ends</u> they should serve."[8]

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[8] Report No. 7 1884 U. S. Bureau of Education. Aims and Methods of the Teaching of Physics; By Professor Charles K. Wead, of the University of Michigan, Page 575.

The report states, "The weight of opinion is decidedly that at first the teaching should be inductive."[9] The reasons offered are that "all our judgments of men, and our opinions on common matters of life must be largely the result of inductive reasoning", and, "more of physics can be taught so as to be remembered in this way than in any other."[10] The difficulties that opposed the introduction of the inductive method are stated as: "absence of any clearly held and generally accepted view of either the importance or the method of inductive training"; "The teacher has probably known little or nothing of it in his own education,---he does not know how to begin"; "he is specially familiar with deductive methods and their value in training"; "the progress of the student following this method is so slow, if measured by the usual examination tests, as to discourage a faint heart"; and last, "It is sometimes carried to such an extreme (at least on paper) as to confine the student's knowledge to what he can learn for himself."[11] The report also states that the average textbook is inconsistent with inductive teaching. The best book on the inductive method is given as Gage's, where experiments and questions precede the statement of principles and laws. Professor Wead in this report warns that "laboratory work and inductive teaching must not be considered equivalent terms".[12]

Physics is recommended for the third year of the course, and the time allowed, a full year. Preparation for Harvard re-

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9 Report No. 7 1884 U. S. Bureau of Education (ante, footnote p.32), Page 683.

10 Ibid., Page 685.

11 Ibid., Page 683.

12 Ibid., Page 705.

quired about two-thirds of a year. New York State regents assigned two-thirds of a year, and Michigan a full year.

The character of the work is described as "elementary and beyond all question experimental"[13], also "primarily for discipline"[14] and training rather than for information.

Practical work in the laboratory is generally favored. It is interesting to note that the English writers were also almost uniformly in favor of laboratory work. Experimenting was to be largely qualitative.

Textbooks with lectures were favored; laboratory work was to <u>accompany</u> textbook study.

The mathematical knowledge that could be assumed was a ready command of arithmetic (including the metric system), algebra through second degree equations, and elementary geometry.

The cost of apparatus necessary as reported varied from $25. to $5000. Two-thirds of the replies placed the cost at not over $300; about one-half put it at not over $150. The feature of home-made apparatus rendered any definite cost difficult.

The majority of replies favored the requirement of physics for admission to college, although many felt that more uniformity in secondary school physics should precede this requirement.

The benefits to be derived from such a requirement are described thus, "The study of physics is fitted to give results in mental training that are of high value and that cannot be given so well by other studies; it is to be considered an essen-

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13 Report No. 7 1884 U. S. Bureau of Education (ante, footnote p.32), Page 695.

14 Ibid., Page 696.

tial subject in the secondary schools; in these it will usually be better taught if the college has even the slight supervision over the teaching that a requirement for admission would give, and so this requirement would react to the benefit of the communities where the schools are situated."[15]

The reasons for teaching physics are "in habituating the pupil to observe for himself, to reason for himself on what he observes, and to check the conclusions at which he arrives by further observation and experiment", and also "the mental training and discipline which the pupils acquire ---".[16]

This report closes with the first syllabus on record. A list of fundamental experiments[17] is given "which may be shown by the teacher, or some of them may be performed by the student in the laboratory." The list is given in full, since it indicates so clearly what was considered fundamental to a course in physics in 1884.

These two reports of 1880 and 1884 present an excellent picture of the unsettled conditions of physics instruction during the first decade of this transition period when physics was changing from a purely book-subject to one involving individual laboratory work.

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15 Report No. 7 1884 U. S. Bureau of Education (ante, footnote p.32), Page 701.

16 Ibid., Page 681.

17 This list will be found in the Appendix (A).

CHAPTER IX

UNIVERSITY INFLUENCE SHAPES SECONDARY SCHOOL PHYSICS TEACHING

About the year 1872 Natural Philosophy disappeared from the curriculum of the high school and its place since then has been occupied by Physics. In that same year Physics had become conspicuous enough in the secondary school program to be recognized by the colleges as one fit to receive credit for entrance. It was also at this time that the high schools began their rapid "gravitation toward the colleges" which continued until the end of the century. By 1884 a few colleges required physics as a prerequisite for entrance on a classical course. Following is a list of such colleges and the requirement (if specified):

Harvard: Rolfe and Gillet or Avery; also two out of four groups of electives. Of these Group IV included Stewart's Lessons ---.
Boston University: Stewart's, B.
Syracuse University: Steele's, or an equivalent.
Lehigh University: Stewart's, Avery's, or Gage's.
Ohio Wesleyan University.
Adelbert College of Western Reserve University: Elementary.
Dennison University: Avery's.
Northwestern University.
University of Denver; Physics.
University of Minnesota: Physics recommended, but not required.

The following list consists of those institutions offering a non-classical course and requiring physics for entrance:

Massachusetts Institute of Technology
Syracuse University
Lehigh University
Ohio Wesleyan University
University of Cincinnati
Dennison University
Illinois Industrial University
Northwestern University
University of Michigan
University of Wisconsin
University of Minnesota
Cornell University, Iowa
University of Colorado
University of Denver
University of California

No definite amount of high school physics work was stipulated except in two cases. The University of Cincinnati required six hours per week for one year; and the University of Michigan required one full year.

In 1886 Harvard College decided to establish a laboratory requirement in physics. This step was the start of a radical change in physics teaching. Woodhull says, in speaking of Elizabeth Mayo's (London) Lessons on Objects, revised by Dr. Shelden and brought out in the United States about 1826, which was very popular and ran through fourteen editions in the next thirty years, "Physics teaching in the high school, before the colleges took a hand in the matter in 1886, was powerfully influenced by this movement to teach from the object rather than from the book and to take into consideration the nature and requirements of the pupil when making a choice of matter and method of instruction."[1]

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1 Woodhull (ante, footnote p.23)

The Harvard Descriptive List issued by Harvard College in 1887 and revised in 1889 with the title 'Descriptive List of Elementary Physical Experiments' was the first definite step taken by the Universities to more or less dictate secondary school physics teaching. This was a list of laboratory experiments defining very accurately the laboratory work necessary to a course acceptable by Harvard for admission credit. The former textbook work requirement, considerably increased, remained as an alternative for those who could not command laboratory facilities. This list contained forty-six experiments, any six of which could be omitted. The criteria for the selection of experiments had been that of practical utility. Hall and Bergen[2] state, "The success of the course has been very gratifying. It is now followed by hundreds of pupils in the schools of New England, and is established in many other places throughout the country", also, "at the examinations for admission to Harvard College, held in 1891, more than half of all the candidates in physics offered this course in place of the alternative textbook course." The success of this Descriptive List was largely due to the fact that at a time when "in view of the inexperience of teachers and the very different standards and methods likely to be adopted by them" the experiments were "carefully thought out and described in much detail". The following statements are taken from the preface to the Descriptive list[3]:

"The objects to be sought in the course of experimental physics which this pamphlet describes may be stated thus: first

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2 Preface, Hall and Bergen, 'A textbook of Physics' (1893 Henry Holt & Co.)

3 Preface, Hall and Bergen.

to train the young student by means of tangible problems requiring him to observe accurately, to attend strictly, and to think clearly; second, to give practice in the methods by which physical facts and laws are discovered; third, to give practical acquaintance with a considerable number of facts and laws, with a view to their utility in the thought and actions of educated men"; "There must be a backbone of quantitative work"; The directions for the experiments were often minute but "are, however, intended to show how the experiments <u>may</u> be done, not how they <u>must</u> be done"; "The teacher should decide for himself how closely these directions are to be followed, and should feel at liberty to substitute for the experiments described other experiments covering equally well the same points ---. This course in all its aspects is intended to occupy the student about five school hours a week, with the usual amount of study out of school, for one year"; "To secure the objects of the course the student during the laboratory period is placed, so far as this is practical, in the attitude of an investigator seeking for things unforetold." To prevent waste of time he must be guided in the proper direction, have probable sources of errors called to his attention, and the <u>established</u> conclusions in the end must always be made known to him.

Mann states, "The influence of the Descriptive List on the development of physics teaching in America has been tremendous. It appeared at the psychological moment when the demand for object teaching, which had made its appearance here about 1848, had reached its full force. It exalted this demand for object teaching into a requirement of quantitative laboratory work.

It showed teachers and school boards how a laboratory method of teaching could be introduced into the work in physics with the use of materials at hand, and with a small outlay for equipment. Its insistence on careful, neat work, and its firm stand for work of a scientific character made its influence on physics teaching a most salutary one for many years."[4] According to Professor Clarke's report in 1880 there were but four schools in the country giving a full year's work in physics with laboratory work by the pupils. Three decades later it was an exceptional school that did not have its physics laboratory and a reasonable amount of apparatus for laboratory work by the pupil. To quote Mann again, "As a result of this movement, the American public high schools now [1912] have laboratories, while the schools in France and Germany are just beginning to secure them."[5]

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[4] Mann, C. R. The Teaching of Physics, Page 58.

[5] Ibid., Page 59.

CHAPTER X

SCIENTIFIC STUDY OF PHYSICS PROBLEMS

Towards the close of the 19th century we find that educational problems were becoming the subjects of scientific study. Because of the significant place that physics was assuming in the secondary curriculum it was only natural that this subject should receive an important place in this scientific study.

The findings of the Conference[1] of Physics, Chemistry, and Astronomy of the Committee of Ten, as reported to the National Educational Association in 1894, contained twelve specific recommendations regarding the teaching of high school physics. These are quoted here to show the trend of physics thinking at this time:

"This Conference recommends:

1. "That the study of simple natural phenomena be introduced into the elementary schools and that this study, as far as practical, be pursued by means of experiments carried on by the pupil; also that in connection therewith, in the upper

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[1] Report of the Committee of Ten on Secondary School Studies with the Reports of the Conferences arranged by the Committee, PP-117-123. American Book Co. 1894.

grades of these schools, practice be given in the use of simple instruments for making physical measurements.

2. "That, wherever this is possible, special science teachers or superintendents be appointed to instruct the teachers of elementary schools in methods of teaching natural phenomena.

3. "That the study of chemistry should precede that of physics in high school work.

4. "That the study of Physics be pursued the last year of the high school course, in order that the pupils should have as much mathematical knowledge as possible to enable them to deal satisfactorily with the subject.

6. "That at least 200 hours be devoted to the study of Physics in the high school.

8. "That both Physics and Chemistry be required for admission to college.

11. "That there should be no difference in the treatment of Physics, Chemistry, and Astronomy, for those going to college or scientific school, and those going to neither.

13. "That in secondary schools Physics and Chemistry be taught by a combination of laboratory work, textbook, and thorough didactic instruction carried on conjointly, and that at least one-half of the time devoted to these subjects be given to laboratory work.

14. "That laboratory work in Physics should be largely of a quantitative character.

15. "That careful note-book records of the laboratory work in both Physics and Chemistry should be kept by the student at

the time of the experiment.

16. "That the laboratory work should have the personal supervision of the teacher at the laboratory desk.

17. "That the laboratory record should form part of the test for admission to college, and that the examination for admission should be both experimental and either oral or written.

21. "That in the instruction in Physics and Chemistry it should not be the aim of the student to make a so-called rediscovery of the laws of these sciences.

22. "That a committee to consist of Mr. Fay and Mr. Krall have charge of making out a list of 50 experiments in Physics, and 100 experiments in Chemistry, to be subject to the approval of the Conference."

The list[2] of experiments recommended above was given as suggestive to those teachers who wished to "know the kind and degree of difficulty of experiments suitable for preparation for admission to college in physics". This list of experiments differed from the Harvard Descriptive List in only two important points: namely, it adds "Find the coördinates of a given curve drawn on coördinate paper, and plot a curve from given coördinates"; and "Relation of the acceleration of falling bodies to the moving force". These two additions, together with the recommendation that physics come in the fourth year so as to insure satisfactory mathematical knowledge, and the selection of experiments that were "suitable for preparation for admission to college", indicate very clearly just how great was the gravitation toward the colleges and toward the university physics during the period 1884-1893.

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[2] This list is given in the Appendix (B).

These recommendations and the list of experiments did not materially change the teaching of physics at that time but rather they found their chief educational value in setting before the teachers of the country the problems that were most urgent of solution.

The Report of the Committee of Ten had no sooner been accepted than a new investigation of the secondary school problem was started. In order to bring the high school and college into closer harmony the National Educational Association in 1895 appointed a committee to study the question of college entrance requirements. This investigation was to have far-reaching effects, and the committee was given the official title of Committee on College Entrance Requirements.

The committee's work was hampered by lack of funds, but was pursued by collecting opinions and statistics. Preliminary reports were submitted at the National Educational Association meetings in 1896 and 1897.[3] The first of these reports showed a wide range of college entrance requirements in physics, such as: of sixty-seven representative colleges, twenty-seven required physics for entrance; ten more would accept physics as an optional subject; and nineteen required no science at all for entrance. Haverford College required elementary physics and human physiology of all applicants in the B.S. course who did not present Latin; and at Bowdoin College the applicant might offer physics or chemistry in place of Greek or Greek History in the B.S. course. The report closes by saying, "In summa-

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[3] Preliminary Report of the Committee on College Entrance Requirements School Review. Vol. 4 No. 6 June 1896. PP 341-460.

tion we notice that while the average requirement is very low, incoherent, and illogical, yet there are 34 institutions recognizing physics, ---".

Meanwhile large numbers of the teaching body of the country had become interested in the problems confronting this committee and it was decided to enlarge the work. This was done by securing the appointment of committees from the New England Association of Colleges and Secondary Schools; the Association of the Middle States and Maryland; the Southern Association; and the North Central Association. These committees were to assist the national committee in its investigations.

The final report[4] of the national committee was presented in 1899 embodying the results of four years of investigation. The following recommendations concerning physics were contained in this report:

1. "That in public high schools and schools preparatory for college physics be taught occupying not less than one year of daily exercises, more than this amount of time to be taken for the work if it is begun earlier than the next to the last year of the school course.

2. "That this course of physics include a large amount of laboratory work, mainly quantitative, done by the pupils under the careful direction of a competent instructor and recorded by the pupil in a note-book.

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4 Report of the Committee on College Entrance Requirements. Proceedings of the National Educational Association 1899.

3. "That such laboratory work, including the keeping of a note-book and the working out of results from laboratory observations, occupy approximately one-half of the whole time given to physics by the pupil.

4. "That the course also include instruction by textbook and lecture, with qualitative experiments by the instructor, elucidating and enforcing the laboratory work, or dealing with matters not touched upon in that work, to the end that the pupil may gain not merely empirical knowledge, but, so far as this may be practicable, a comprehensive and connected view of the most important facts and laws in elementary physics.

5. "That college-admission requirements be so framed that a pupil who has successfully followed out such a course of physics as that here described may offer it toward satisfying such requirements."

The committee recommended that physics be given the third year of the course with at least four periods a week throughout the year. It also emphasized the value of building the curriculum around a certain number of constants, one of these being a unit of science.

The report also contained an "Outline of Laboratory Work in Physics for Secondary Schools" suggested by Professor E. H. Hall of Harvard University, chairman of the physics committee of the Association. Professor Hall's suggestion was that at least thirty-five exercises be selected from a list of sixty or more, similar to those in the list of sixty-one which he presented.[5]

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[5] Professor Hall's list of experiments are given in Appendix (C).

Ten or more were to be selected from mechanics; the exercises in light were optional; and each remaining division was to be represented by at least three exercises. The list is divided into two parts, the object being to encourage the beginning of the study of physics early in the school course. The experiments in the first part are adapted to young pupils.

Professor Hall writes, "In this supplementary part of the report the matter relating to physics is little more than the Table of Contents of the Harvard Descriptive List and two paragraphs taken, almost without change, from the introduction to the list".[6] Also, "on the subject of this chapter (Physics in Various Kinds of Secondary Schools) we have something approaching the authority of official utterance in the various publications of the National Education Association during the past ten or twelve years".[7] However, the "authorities of official utterance" had neglected in the Report of 1899 to guide the teacher in his class room work as to the selection of subject-matter or appropriate method of presentation. The result was that textbook writers of the time assumed this burden and their books during the next few years show how they helped to fix the course in physics.

As soon as the Report of the Committee on College Entrance Requirements had been adopted, including, as it did, the Harvard Descriptive List, now backed up by the "authority of official utterance", a number of apparatus companies placed on the market complete outfits for doing all the experiments in this list.

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[6] Smith and Hall. Teaching of Chemistry and Physics in Secondary Schools, Page 329.

[7] Ibid., Page 327.

This 'National Physics Course' was adopted extensively throughout the country and exerted a tremendous influence toward fixing the nature of the course.

To show how firmly this 'National Physics Course' had become intrenched by 1906 needs but an examination of an investigation[8] conducted that year by a committee of the Central Association of Science and Mathematics Teachers. A questionaire containing one hundred and one experiments was sent out to physics teachers in all parts of the country and two hundred and seventy-five replies were received. Each teacher checked those experiments he considered essential to the course. Forty-seven experiments were voted essential by the majority of replies, and twenty-nine of these were declared to be essential by two-thirds of the replies. Of the forty-seven experiments considered essential, thirty-six were contained in the Harvard list as contained in the Report of the Committee on College Entrance Requirements; and of the twenty-nine experiments voted essential by two-thirds of the replies, twenty-six were in that list.

The Harvard Descriptive List stands out as a decided asset to the teaching of physics for a number of years after its publication in 1887. It resulted in the establishment of laboratories and emphasized measurements and quantitative work. But, as Mann states, "When, however, it became clothed with the 'authority of official utterance', and was baptized 'National Physics Course' by the apparatus dealers, its vitality was gone. It has now [1912] become an institutionalized form, which, like all such

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[8] A New Movement Among Physics Teachers, Circular II, School Review. Vol. 14 June 1906, Page 429.

forms, first blocks the way of progress, and then fades away".[9]

An exhaustive study of these two reports, namely, the Report of the Committee of Ten, and the Report of the Committee on College Entrance Requirements, shows that two vital problems in the teaching of Physics were becoming recognized. To the present day these same two problems are receiving much pedagogical attention. They are: first, the problem of the differentiation of the course in physics to meet the demands of the various classes of pupils who study the subject; and second, the problem of the method of teaching physics.

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[9] Mann, C. R. The Teaching of Physics, Page 65.

CHAPTER XI

SECONDARY SCHOOL PHYSICS BECOMES TOO MATHEMATICAL AND ABSTRACT

In practically all the textbooks in Physics published before 1870 we find very few expressions of principles in algebraic form. The diagrams also were almost always taken from the actual thing, and geometrical representation of simple machines was practically unknown. In the preface to Olmsted's Natural Philosophy for Schools and Academies (1838) the author says the text includes "exhibitions of the principles of Natural Philosophy with very copious applications of them to the arts and to the phenomena of nature". Again, in the preface to Quackenbos' Natural Philosophy (1859) we read, "Exhibiting the applications of scientific principles in everyday life". Even in the preface to Avery's First Principles of Natural Philosophy (1884) the author says - "Especial care has been taken to provide simple, teaching experiments which do not require expensive apparatus. The latest developmentsof science, such as the introduction and use of electrical units, have been freely utilized; the mere polemics of physics has been ignored". The experiments are qualitative in character and the book contains but a few simple mathematical problems.

By the end of the century textbooks had undergone a radical change. In 1895 Avery's School Physics was issued, and in its preface we read, "In this book will be found an unusual number of problems. --- For several years there has been a growing tendency in the high schools of the country to indulge in laboratory methods. An effort has been made to adapt this book to such needs". In accordance with this last statement, a large number of quantitative experiments are given. Carhart and Chute's Elements of Physics published in 1896 states in the preface that "the time-honored recitation method has gone out and the laboratory method has come in". It condemns the "original discovery" method and claims: "Before the pupil is in any degree fit to investigate a subject experimentally, he must have a clearly defined idea of what he is doing, an outfit of principles and data to guide him, and a good degree of skill in conducting an investigation". The book's aim is defined to "formulate clear statements of laws and principles", and puts physics on a mathematical basis by reducing laws and principles to mathematical formulas, and uses many problems to give the pupil ability to manipulate these formulas and to interpret physical laws in terms of mathematics. This book was perhaps the most scientific textbook in physics that had yet appeared for use in the secondary schools, and is an excellent representative of that class of textbooks which made of physics teaching an extremely mathematical and technological one by the end of the century.

Chute's Physical Laboratory Manual (1899) likewise emphasized accuracy of observation and measurement by making the

problems quantitative, or in the words of the author, "The educational value of practical physics does not lie in the so-called discovery of laws, nor in the experimental demonstration of principles. --- But, rather, its value lies in the training it gives in attention to details, in the cultivation of accuracy in observing the smallest changes, in the formation of systematic methods of working, in developing the ability to reason back to a general law from a particular set of observations, and in cultivating habits of precise expression of ideas and principles on the pages of the note-book. ---"

The reasons for the extreme development of the mathematical and abstract in physics teaching were contributed from the following sources:

The Committee of Ten had demanded specially trained teachers and quantitative work in the laboratory. The Committee on College Entrance Requirements contained the following resolution: "Resolved, that the teachers in the secondary schools should be college graduates, or have the equivalent of a college education", saying that, "The time is past when a superficial knowledge of a variety of subjects, coupled with a knack for giving instruction and some administrative ability, can be considered sufficient qualifications for teaching in our high schools. ---" This demand for specially trained teachers brought into the schools men and women who were inclined to teach from the college point of view, with its research and mathematical basis. Another contributing factor was the influence of the college entrance examinations. The high school that wished to enter its graduates in the leading colleges of the day was forced to

meet the demand for a scientific training in physics. Last of all, we have the textbook writers who were often college or university instructors, or secondary school teachers with special university training in physics.

These various forces operated to put physics teaching on a scientific basis, and to make of the high school a stepping stone to the university. We thus see the high school laboratory transformed in about two decades from the elementary experimenting room where Gage's pupils turned out notebook records at the rate of one experiment every twelve minutes - five an hour - to a scientific workshop where the pupil measured, weighed, observed, and tabulated the data on thirty-five to forty exercises in a full year's course of about one hundred and fifty laboratory hours.

The end of the century also saw teachers and textbook writers take a more rational view of the importance of the laboratory emphasis in physics teaching. The change from a purely book course to one involving individual laboratory work, as with most radical changes, had been indulged in to an extreme, and the pendulum now began to swing back again. Chaotic conditions existed as a result of this over-emphasis of laboratory work to the practical exclusion of the textbook method.

The textbook writers picture the conditions at the end of the century clearly in the following quotations, taken from the prefaces of several textbooks of this period. Carhart and Chute (1892) say, "A few years ago it seemed necessary to urge upon teachers the adoption of laboratory methods to illustrate the textbook; in not a few instances it would now seem almost

necessary to urge the use of a textbook to render intelligible the chaotic work of the laboratory". Avery (1895) writes, "The class-room work must be kept ahead of the laboratory work ---". In Henderson and Woodhull's text (1900) we read, "Both laboratory and classroom work are essential to a correct knowledge of elementary physics, and they should correlate". Torrey's Chemistry (1899) stresses the situation by the remark, "Chemistry has suffered from the irrepressible wave of laboratory madness which has swept the whole educational world".

It was also at this time that educators began to question the infallibility of the inductive method. Carhart and Chute (1892) describe very clearly how the inductive method or attempt at it results in failure. Neither does Avery (1895) appear to think that high school pupils can work by the inductive method. Hortvet (1899) even goes so far as to say in the preface of his textbook, "It is found in practice that the purely inductive method fails at points where it is expected to do the most good."

CHAPTER XII

DIFFERENTIATION OF THE SECONDARY SCHOOL COURSE AND ITS EFFECT ON PHYSICS TEACHING

The Committee of Ten sought to establish a uniform requirement for entrance to college, and consequently a uniform high school course, despite the constant tendency in the opposite direction. The preliminary report of the Committee on College Entrance Requirements in 1896 had stated, "In pleading for a uniformity in college entrance requirements there are a few vital facts which cannot be ignored: First, the triple function of the public high school, namely, to equip pupils for the business of life; to give a proper training to those who will teach in the common schools; and to prepare for college. Secondly, a majority of our young people who go to college, come to a decision late in their secondary course. Thirdly, every young man or woman who has successfully devoted at least four years to earnest study in a well-equipped secondary school, should be admitted to any college in the country, whether such a pupil has devoted the greater part of his time to Latin, Greek and mathematics, or to Latin, modern languages and mathematics, or to Latin, mathematics

and the sciences, or to any other combination of studies, which has developed his power and been in harmony with his intellectual aptitudes. To this end, a secondary course of study should be thoroughly elastic and with varied electives, suited to the talents of the individual child; a college course should be still more elastic and with a large number of electives ---".[1] In its final report (1899) these ideas were put in the form of resolutions together with a resolution recommending that physics in college be a suitable sequel to high school physics and not a repetition.

Gradually, as the elective system in the secondary schools gained ground, the colleges slowly let down the bars in their entrance requirements and permitted a wider range of subjects to be offered for admission.

But back of this entire movement to widen and diversify the channels of education we find an even stronger force - the same one that operated to first put science into the secondary schools, and later to help establish the laboratory method - namely, the economic and industrial demands of the people. The Committee of Ten said, "The secondary schools of the United States, taken as a whole, do not exist for the purpose of preparing boys and girls for colleges. Only an insignificant percentage of the graduates of these schools go to colleges or scientific schools. Their main function is to prepare for the duties of life that small proportion of all the children in the country - a proportion small in number, but very important to the welfare of the nation - who show themselves able to profit by an education prolonged to

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[1] School Review Vol. 4 No. 6 June 1896 Page 422.

the eighteenth year", also, "A secondary school programme intended for national use must therefore be made for those children whose education is not to be pursued beyond the secondary school. The preparation of a few pupils for college or scientific school should in the ordinary secondary school be the incidental, and not the principal object". Thus the schools began to recognize their function as that of equipping pupils for life, and the adoption of the elective system in its course of study was inevitable.

With the uniform high school course, and often the required study of physics, the colleges had been able to require and demand the mathematical and abstract type of physics in the high school. But with the adoption of the elective system the former compelling forces, such as graduation from the high school or admission to college, disappeared, and it began to be recognized that unless the type of physics then in vogue and which did not appeal to the average boy or girl, was radically changed, a depopulation of the physics classes would naturally result. With the physics course on an optional basis its election became less and less frequent except by those who wished to enter a higher scientific school. Thus, beginning with the twentieth century and continuing even today we find that a reform movement has come about in physics teaching so that it may better serve its proper function toward the great masses of the school population, namely, to teach the applications of physics to life.

CHAPTER XIII

PHYSICS TEACHING IN THE FIRST DECADE OF THE TWENTIETH CENTURY

This reform movement in physics teaching in the United States has been chiefly the result of voluntary action of the teachers themselves in trying to work out their own methods and be a factor in shaping the educational system. Its aim can be described as "the vitalizing of physics teaching". Secondary school teachers throughout the country during the first decade of the new century were trying to popularize physics by making it a live and interesting subject, full of information about phenomena of everyday life.

C. R. Mann describes the spirit of the movement by comparing the old with the new. Of the old ideas of science he says, "These definitions make of science a large museum of classified and organized facts, carefully arranged in glass cases, each of which bears prominently the inscription, 'Hands Off'. The student is invited to inspect our collection, and to learn the names and order of our well-arranged curios; but he is not as a rule asked to take part in their organization, nor is he even given a chance to find out what the methods and processes of such organization

are". Of the new ideas, he says, "We have only to arrange the material so that each fact appears as a step in the process of obtaining a more general result, instead of presenting it as a separate and distinct result by itself. Then science appears as an organizing process rather than as an organized result".[1]

Two books appeared in 1906 embodying the principles of the reform movement; one was A First Course in Physics by Millikan and Gale, and the other was Physics by Mann and Twiss. In the preface to Millikan and Gale we find, "The books [text and manual] represent primarily an attempt to give concrete expression to a rapidly spreading movement to make high school physics, to a less extent than it has been in the past, either a condensed reproduction of college physics, or a mathematical and mechanical introduction to technical science, and to a greater extent than it has heretofore been, a simple and immediate presentation, in language which the student already understands, of the hows and whys of the physical world in which he lives." In the preface to Mann and Twiss we read, "We have endeavored to strengthen the presentation of the subject, and aid the teacher in three ways: I. By arousing interest. II. By developing the scientific habit of thought. III. By presenting some of the principles from the historical standpoint", and "Interest is rarely stimulated in youth by elegant and abstract mathematical treatment; nor is it often aroused by rigorous logical demonstrations. It is aroused by beginning with some concrete thing that goes - something that is already familiar".

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[1] School Review, Vol. 14 November, 1906. C. R. Mann, Science in Civilization and Science in Education, PP 664-670.

The last statement is characteristic of the new texts of this decade. The student is brought to the physical laws and principles by commencing the study with familiar knowledge. Some of the more abstract topics were omitted and the rest were stated in clear understandable language, from the experimental and historical points of view. Both of the above textbooks retained most of the mathematical formulas and the mathematics, but tried to present the subject from the viewpoint of everyday life rather than from the mathematical standpoint - thus, helping to meet the demands of the reform movement for better methods.

The first five years of the century saw no concerted action on the part of teachers to bring about the needed reforms. However, various writings and discussions in all parts of the country during these years were giving progress and stimulus to the reform movement.

In 1905 the Central Association of Science and Mathematics Teachers appointed a committee of three to consider the advisability of approving the list of experiments adopted by the National Educational Association in the same year, as suitable for a high school course of one year in physics, also "to take such other steps as might seem desirable for strengthening the work in elementary physics". A circular containing a list of experiments, compiled by combining lists proposed by the North Central Association of Colleges and Secondary Schools and the National Educational Association, was sent out to a large number of physics teachers in order to get a consensus of opinion concerning the kind and amount of work that should be done in a

year's course in laboratory physics. The answers received showed a wide variation of opinion on several phases of physics teaching, and in the experiments considered essential. They showed also such wide-spread interest in the problems at hand that it was decided to enlarge the work of the committee and conduct it toward the specific end of determining a definition of the physics unit and the making of a satisfactory syllabus for it. In accordance with this plan the committee invited various interested associations to appoint committees to coöperate in this work. Committees were appointed from: North Central Association of Colleges and Secondary Schools; Michigan Schoolmasters' Club; New York State Science Teachers' Association; the American Physical Society; New Jersey State Science Teachers' Association; Chicago and Cook County High School Teachers' Association; New York Physics Club; Missouri Society of Teachers of Mathematics and Science; and a little later from The Indiana State Science Teachers' Association; the Pacific Coast Association; and the Eastern Association of Physics Teachers. The joint committee consisted of forty-eight members and organized themselves into a permanent National Commission on the Teaching of Elementary Physics with Professor C. R. Mann as their first chairman.

The commission continued the work already begun with the two-fold purpose, as stated in one of its circulars: "First, to find out just what is wanted by the teachers as a whole for the improvement of physics teaching; and second, having found this out, to attempt to secure it for them". The work extended over a period of two and a half years, or till the middle of 1908, six circulars in all being sent out in an effort to investigate

the conditions of physics instruction, the proper physics unit and syllabus, and the secondary school - college relations.

The results obtained did not solve the difficulties but did materially help in crystallizing these difficulties for the teachers of the country. They revealed the wide and varied disagreement among physics teachers as to the fundamental principles of their work, and the lack of harmony between secondary schools and colleges in regard to the proper continuation of the physics course. They also helped to clear up the questions of: the proper proportion of qualitative and quantitative work; the proper amount and relation of mathematics; and the agreement of a uniform course for all schools. The committee's specific aim was accomplished in the publication of a definition of the unit in physics and a syllabus of required topics to go with the unit.[2] The report of the national commission was adopted by the various members of the commission, the only dissenting opinions, which were voiced by several, being "that a uniform course in physics for all schools is both undesirable and unattainable"; "that syllabuses should deal with the barest outline of general principles, leaving each teacher free to fill up the course according to his best judgment"; "that examinations for college entrance should be confined to the general principles specified in the syllabus ---"; and "that a syllabus was not desirable."

Having finished this investigation the National Commission decided in 1908 to organize a symposium to determine "What should be the purpose of the instruction in physics in the secondary schools?" Twenty men, representing psychologists, educators, college physicists, and normal and secondary school men were invited to participate in the symposium. It was carried

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[2] This unit in physics, and syllabus are given in Appendixes (D) and (E).

on through the pages of the periodical School Science and Mathematics from December, 1908 to March, 1909. Such men as Nicholas M. Butler, John F. Woodhull, Henry Crew, H. M. Chute, G. Stanley Hall, Albert A. Michelson, George R. Twiss, R. A. Millikan, John Dewey, and others equally as prominent in educational work, sent in contributions. The results showed considerable disagreement as to the specific function of physics in the high school, but the majority of opinions favored the idea that the pupil should be taught to comprehend the world about him; that physics should be a living subject, appealing to the interest of the pupil; and that mathematics and measurement were of secondary importance in the study of elementary physics.

During the last half of this first decade practically all science organizations throughout the country were taking an active interest in investigating various local and general problems, and from the results, attempting to determine scientific methods. It was during this period that the American Federation of Teachers of the Mathematical and Natural Sciences was formed. This Federation was composed of seven of the prominent science associations of the country and its purpose was to serve as a 'clearing house' for its members. In 1908 it became affiliated with the American Association for the Advancement of Science and President H. W. Tyler was elected as the Federation's representative to the Council of the Association. Thus, this period saw built up a more effective grouping of those interested in science in order to "promote the advancement and improvement of science teaching."

Another outstanding feature of this period was the vast amount of discussion aimed at improving physics teaching. No

part of the country or of the subject was neglected, and the educational and professional magazines of the country distributed the discussions far and wide. The weight of opinion favored the practical, the industrial, and the applied science and denied the mathematical and abstract type. It was emphasized that physics must be taught so that the pupil would understand the world about him in terms of his own life and experience.

Frank B. Spaulding, of the Boys' High School, illustrates the spirit of the time in his talk before the Physics Club of New York on the subject, "What Knowledge [of Physics] is of Most Worth?"[3] by stating the following four propositions:

1. "The interests and needs of the pupil should be the determining factor in the arrangement of courses and the choice of method.

2. "It follows that a high degree of uniformity in teaching physics is neither practical nor desirable.

3. "Wherever practical, different courses should be provided for girls and boys.

4. "Physics should be taught not as a preparation for college but as a preparation for life."

Similar articles throughout the country were stressing the need of teaching physics from the standpoint of the pupil, rather than from the standpoint of the subject.

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3 School Science and Mathematics. November, 1908.

CHAPTER XIV

COLLEGE REQUIREMENTS ARE MODIFIED TO MEET THE CHANGES DEMANDED BY THE REFORM MOVEMENT

It was quite essential to the success of the reform movement that there should be better correlation between the colleges and the secondary schools. The two most potent factors that had kept secondary school physics on a quantitative and mathematical basis were the college entrance requirements and the university-trained specialists in the secondary schools. There was much agitation for greater freedom on the part of the high school to shape its own course, and for more liberal provision on the part of the colleges to accept, for entrance, such courses in physics as the secondary schools, under their varied conditions, could successfully give.

Part of this agitation came from college professors themselves, who began to recognize that secondary school physics demanded a more elementary and less rigidly scientific and mathematical presentation than advanced physics. Professor George H. Mead, of the University of Chicago, wrote that the "university influence upon the study of science has not been

fortunate,"[1] resulting in the isolation of science from the experience of the child, from the other sciences, and from the language in which in a large degree it must be expressed; also in restricting the extent of the field of high school science. Professor R. A. Millikan, also of the University of Chicago, in discussing Professor Mead's paper, said, "This influence has been unfortunate (1) because it has tended to force university methods and university material into a sphere of education to which they are wholly unsuited, and (2) because it has tended to restrict high-school physics to too narrow a field, making it, to too large an extent, a minute study of the mathematical and mechanical foundations upon which technical science is built, rather than an inspiring insight into the meaning of the physical world."

Regarding the influence of the graduate instruction of the universities upon the instruction in the secondary schools Thomas K. Balliet, Dean of the School of Pedagogy of New York University, wrote, "The highly specialized training of the best graduate schools seems to make it difficult for the young teacher to view his work from the standpoint of his pupils rather than from that of his subject."[2] He suggests a remedy by having the graduate school make a distinction between two classes of students - those preparing to teach in universities and colleges, and those preparing to teach in the secondary

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1 School Review April, 1906.

2 Paper read before the Association of Colleges and Preparatory Schools of the Middle States and Maryland, November, 1907.

schools, the latter group being permitted to work in a broader field, without the narrow specialization of the former group. He deplores the existing general conditions by saying, "That this 'domination of the colleges', as it is termed, is, however, not always wholesome, is indeed, in some respects to a marked degree harmful, is a familiar fact."

President David S. Jordan, of Stanford University, wrote, "The high school as thus defined has these duties clearly indicated: to give a rounded development of physical and mental powers, so that no line of talent shall perish by default; it should indicate and emphasize that form of ability which will count for most in the conduct of life and it should do its foundation work with such thoroughness that the higher education may be built upon it with the certainty that the attainments shall be solid so far as they go. This is all that the colleges and universities have the right to ask, and for them to specify certain classes of subjects regardless of the real interest of the secondary schools and their pupils is a species of impertinence which only tradition justifies. To demand thoroughness of secondary instruction and to enforce this demand in any practical way is the duty of the college, but the question of what the high schools shall teach is a question for those schools to decide for themselves."[3]

By the year 1910 it was evident that there was a decided tendency on the part of colleges and universities to allow the secondary schools a greater part in forming college entrance requirements. At a meeting of the College Entrance Examination

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3 Popular Science Monthly, July, 1908.

Board on May 11, 1907, the constitution was amended by adopting the article "The chairman of the Board shall, with the approval of the executive Committee, appoint annually a Committee of Review, to consist of seven members, three of whom shall be representatives of secondary schools. ---". This Committee of Review was to consider all criticisms and recommendations received, and to make definite recommendations in regard to modification of the requirements.

In the report of the Commission on Accredited Schools and Colleges of the North Central Association of Colleges and Secondary Schools for 1910, the definition of the unit in physics, as adopted by the last Association in 1908, was revised. Sections five and six were made to read as follows:

5. "In the laboratory the student shall perform at least thirty individual experiments, and shall keep a careful notebook record of them. At least twenty of these should involve numerical work and the determination of such quantitative relations as may be expressed in whole numbers. Such quantitative work should aim to foster the habit of thinking quantitatively, but should not attempt to verify laws with minute accuracy nor to determine known physical constants with elaborate apparatus. The list of topics covered by these quantitative experiments should not differ widely from the list of starred topics in the syllabus.

6. "The classwork should aim to build up in the student's mind clear concepts of physical terms and quantities, and an intuitive appreciation of the general principles which make up the syllabus. He must be trained in the use of these principles in the solution of simple, practical, concrete numerical problems."

The College Entrance Examination Board issued a document December 1, 1910 containing a full statement of its requirement in physics. It approved the following general definition of a unit: "A unit represents a year's study in any subject in a secondary school, constituting approximately a quarter of a year's work," which had been formulated by the National Conference Committee on Standards of Colleges and Secondary Schools. The Board's general statement on the unit in Physics was as follows:

1. "The Course of Instruction in Physics should include:

(a) "The study of one standard text-book, for the purpose of obtaining a connected and comprehensive view of the subject. The student should be given opportunity and encouragement to consult other scientific literature.

(b) "Instruction by lecture table demonstrations, to be used mainly for illustration of the facts and phenomena of physics in their qualitative aspects and in their practical applications.

(c) "Individual laboratory work consisting of experiments requiring at least the time of 30 double periods, two hours in the laboratory to be counted as an equivalent of one hour of class-room work. The experiments performed by each student should number at least 30. Those named in the appended list are suggested as suitable. The work should be so distributed as to give a wide range of observation and practice.

"The aim of laboratory work should be to supplement the pupil's fund of concrete knowledge and to cultivate his power of accurate observation and clearness of thought and expression. The exercises should be chosen with a view to furnishing force-

ful illustrations of fundamental principles and their practical applications. They should be such as yield results capable of ready interpretation, obviously in conformity with theory, and free from the disguise of unintelligible units.

"Slovenly work should not be tolerated, but the effort for precision should not lead to the use of apparatus or processes so complicated as to obscure the principle involved.

2. "Throughout the whole course special attention should be paid to the common illustrations of physical laws and to their industrial applications.

3. "In the solution of numerical problems, the student should be encouraged to make use of the simple principles of algebra and geometry to reduce the difficulties to a solution. Unnecessary mathematical difficulties should be avoided and care should be exercised to prevent the student from losing sight of the concrete facts in the manipulations of symbols."

This definition of the unit was accompanied by a syllabus which included a detailed outline of the fundamental topics of a year's course in physics, and a list[4] of experiments, selected so as to meet the requirement for a laboratory course.

In June, 1911, Harvard University put into effect a new plan of admission, which was not intended to displace the old plan but to supplement it and to make possible the admission of promising students who, under the old plan, would be barred on account of not having fulfilled the requirement for a prescribed course of study. Under the new plan a student might be admitted upon presenting a detailed statement of his secondary school

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[4] This list is given in Appendix (F).

work and passing an examination in four subjects. The statement must show that the student had covered an approved high school course satisfactorily, and must give in detail the subjects and ground covered, time devoted to each subject, and quality of work done. The student must have had a four years' course, and confined his work chiefly to the subjects of languages, science, mathematics, and history - none of these subjects being omitted. Two studies must have been pursued sufficiently to satisfy the requirements of the College Entrance Board or the advanced Harvard entrance examination.

Having met all these requirements the student might present himself for examination in four subjects: (a) English; (b) Latin, or for candidates for the S.B. degree, French or German; (c) Mathematics, or Physics, or Chemistry; (d) Any subject not already elected under (b) and (c). The student was admitted, if at all, without condition, failure to pass any of the examinations barring admission.

The University of Chicago also adopted an entirely new plan of entrance requirements in 1912. The essential features of the new plan were: The student must present by certificate from an approved school or by examination 15 units of entrance credits. Among these there must be 3 units of English, and in addition 1 principal group of 3 or more units, and at least 1 secondary group of 2 or more units. The additional groups were to be selected from the following subjects:

1. "Ancient Languages (Greek and Latin), it being understood that to make a group of 2 or of 3 units the work must be offered in a single language.

2. "Modern Languages other than English, ---.

3. "Ancient History, Mediaeval and Modern History, English History, United States History, Civics, Economics.

4. "Mathematics.

5. "Physics, Chemistry, Botany, Zoology, General Biology, Physiology, Physiography, General Astronomy.

"In group 5 not less than 1 unit may be offered in either Physics or Chemistry. Any combination of the subjects within each group is permitted.

"Of the 15 units offered for entrance at least 7 must be selected from the subjects in groups 1 to 5. Not less than 1/2 unit may be offered in any subject.

"The remaining 5 units may be selected from any subjects for which credit towards graduation is given by the approved school from which the student receives his diploma; but Greek, Latin, French, German (or any language other than English), Mathematics, Physics, and Chemistry, if offered, but not as above under 1 and 5, must each consist of at least 1 unit. --" Students would not be allowed to enter with conditions.

It is very evident from what has been said that there was a strong tendency in entrance requirements in the direction of wide election of subjects in the secondary school course. This together with the liberal choice of subject matter permitted by the new definitions of the physics unit, and lists of experiments emphasizing clear conceptions of principles with less use of algebraic formulas, shows that the colleges and universities were gradually allowing the secondary school to work out its own courses. Students could now enter Harvard or the University of

Chicago by offering physics without examination and without the fulfillment of a rigidly prescribed course. Methods of physics teaching and a content of the subject that would 'vitalize' secondary school physics were rapidly becoming established facts.

CHAPTER XV

EFFORTS TURN TO EFFECTIVE METHODS OF INSTRUCTION

The second decade of this century saw the gradual change from the tasks of defining units and determining the number of experiments to the vital problem of finding the most effective method of applying the accepted plan of teaching. The textbooks of the period endeavored to include such material and present it in such a manner as to appeal to the every-day interests and common knowledge of the pupil. Popular textbooks in use were Millikan and Gale's A First Course in Physics (1906); Crew and Jones' Elements of Physics (1909); and Linebarger's Textbook of Physics (1910). Typical statements in the prefaces to such books were: "The book attempts to give a simple and immediate presentation in language which the student already understands, of the hows and whys of the physical world in which he lives"; and "Appeal to the everyday experience not only of boys but also of girls - show them physics as a science of daily life - assist the pupil in explaining the material phenomena of the world about him." The revised edition of the Mann - Twiss (1910) eliminated much of the abstract material of the first edition, and divided the book into two parts: the first designed to meet the requirements

of the definition of the physics unit as adopted by the North Central Association of Colleges and Secondary Schools, and the latter part intended for those desiring to pursue scientific professions. The first part practically eliminated algebraic formulas.

The first part of this decade also saw the weakening of the emphasis upon the disciplinary aim that had been so strongly intrenched for the several preceding decades. Educators were questioning whether physics was able to give automatically the mental training it was supposed to give. The new aim of meeting the practical needs of the pupil in meeting life situations was rapidly finding favor to the disadvantage of the mental discipline aim.

Having in the schools a fairly well established plan of teaching physics - recitation, lecture and demonstration work, and a rather definitely defined course in laboratory experiments - we find the bulk of this decade's discussions, scientific meetings and writings on trying to find the best method of effecting this plan. Most physics teachers agreed that their work was twofold: to prepare a certain number for higher schools; and to prepare the great mass, who go directly out into their various occupations, to interpret everyday life in terms of scientific principles and make them better citizens.

J. M. Jameson, of Pratt Institute, calls attention to the movement for industrial training, and the consequent need for adjusting physics teaching to meet the demand of the people; and indicates the spirit of the period when he says, "It is time for physics teachers to recognize and discuss the situation fully,

for there can be no question as to the continued growth of the educational ideas of which the present agitation for industrial education is a direct outcome. These ideas appeal to the business sense of the public, and command, therefore, the support of manufacturers, of labor organizations, and of business men of all classes, who see in a school training for industrial life both the good of the community and advantages to their children, which they themselves did not enjoy but which experience has taught them would have been of inestimable service, and which the public schools, as now organized, do not provide."[1] Herbert Brownell, Teachers College, The University of Nebraska, writes, "It is my own thought that the laboratory work is or should be made the center and heart of all high school science teaching. There it is that the pupil makes his study of things and of phenomena, and exercises himself in intelligent observation, seeking to understand what is noted and to interpret his observations. The requirements of experimental work and its allied exercises constitute a series of difficulties to be mastered, of problems whose solution is sought. And it is to be noted in passing that in the selection and adaptation of such a laboratory course there is need to see to it that each succeeding exercise possesses an inherent interest and worth which invites to earnest endeavor."[2] One more quotation will be made to show the trend of physics thinking during this period. Philo F. Hammond, of Palo Alto, California, writes, "Physics should be an applied science - should always have been an applied science. And when I say

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[1] School Science and Mathematics. March, 1912.

[2] " " " " April, 1913.

'applied' I do not mean applied to something the student can use to earn a livelihood, but rather that physics should be taught in such a way that the student can and will apply the principles learned to things about him with which he comes in contact every day."[3] These quotations are typical of the writings of the day and show that those closest to the problem were beginning to realize that the main end to be sought in physics teaching is social efficiency, and that the laboratory method must be depended on to successfully secure this end.

One of the methods used to improve laboratory work was the numerous suggestions and devices that appeared in the writings of the time made by teachers who had found them especially successful in their own laboratories. This movement took on the aspects of a major role when the American Federation of Teachers of the Mathematical and the Natural Sciences in 1912 appointed a committee of physics teachers "to co-ordinate new apparatus and new teaching content with the present secondary school physics course." The report of the Federation went even so far as to say, "The general committee will probably form a new definition of the 'Physics Unit' to correspond with what they find to be the most improved usage in the subject, and will perfect machinery by which every physics teacher in the country can secure the most improved forms of equipment." All teachers of physics who had originated any designs and exercises were asked to contribute them in the interest of instruction improvement, and School Science and Mathematics during 1913 and 1914 published many pages of the contributed material.

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[3] School Science and Mathematics. December, 1913.

Although the committee's work did not result in a new outline for the course, it helped to spread the most successful ideas of the day throughout the country, and aided in evolving a course that had a greater cultural and vocational background.

CHAPTER XVI

REORGANIZATION OF THE SCIENCE CURRICULUM

The National Education Association in 1911 received a report from its committee on the articulation of high school and college which urged the modification of college entrance requirements so that secondary schools could adapt their work to the varying needs of the students, and at the same time give them such training as would render them eligible to enter college. This was the first step in a movement that was to have a tremendous influence on secondary school education, and resulted in the formation of The Commission on the Reorganization of Secondary Education, appointed by the National Education Association, and which undertook the complete reorganization of the entire educational program of secondary schools. A reviewing committee consisting of the sixteen committee chairmen and ten members at large was organized to assist the sixteen committees of the commission through constructive criticism of their reports.

To show the need of such reorganization in physics teaching as this Commission was about to undertake in the whole field of education, let us examine the results of two investi-

gations made about this time.

Earl R. Glenn[1], in June, 1913, reported the results of an investigation of the general practice in the teaching of physics in the state of Indiana, which probably may be taken as representative of the practice of the country at large. His study revealed that fifty-two per cent of the high schools reporting gave physics in the fourth year, and thirty per cent in the third year; sixty-one per cent made physics optional; that thirty-five per cent required physics for graduation; that the laboratory work was not so well organized as the textbook work; and that approximately one-third of the schools studied were not using the time allotment for laboratory and recitation work generally conceived to be the most desirable.

A committee appointed by the Central Association of Science and Mathematics Teachers in 1912 to formulate a complete science course for the four years of the high school made a preliminary report in 1913. In this report[2] it stated that as the various sciences had become differentiated they had gained places in the curriculum until eight, or even twelve, were found in a single state. Furthermore it says, "These numerous sciences are contending with one another for a place in the high school, instead of presenting a demonstration of the efficiency of unified science in the high school. The need of unification of sciences is apparent to any one who has studied the schools at first hand."

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[1] School Science and Mathematics June, 1913.

[2] School Science and Mathematics.

The question as propounded by the committee was, "What should science do for high school pupils?" The answer to this question was to form the basis for the organization of science in the high school. This basis as given in the report is as follows:

1. "High school science should give pupils such a knowledge of the world of nature as will help them to get along better in the course of everyday life.

2. "Science can not help people in fundamental ways in everyday life without serving to make better people. The truths of science are the truths of life, and while one may for a time divert the verities of nature, the fundamental laws of science eventually correct these errors. While science, therefore, should enable people to get along better, it does so by improving the people through their improved attitude and intelligence in their work, and this means increased efficiency.

3. "Science should stimulate pupils to more direct and purposeful activity and should help them to choose intelligently for future studies or occupations. This purpose is common between science and other subjects of the curriculum, but cannot be omitted from science because of the very large number of ways in which science is used in the world of affairs.

4. "Science should give pupils methods of obtaining accurate knowledge, which method should assist in solving the pupil's own problems. It should develop an abiding belief in the value of accurate knowledge and the danger of dependence upon any other kind of knowledge.

5. "Science, by giving a greater and clearer knowledge of nature, should give them greater, clearer and more intelligent enjoyment of life."

The committee followed this statement by a broadly outlined course: the first year to contain, first, an introduction to science in general, involving fundamental principles of various sciences and using materials from all, if necessary; and second, the subject of physiology and hygiene combined with physical education, as a complete course of instruction on the human body. The second year should also contain fundamental principles of various sciences and their applications, as necessary to a scientific understanding of food, clothing, shelter and commerce. The third and fourth years should contain elective sciences, such as: physical and chemical science, domestic science, agricultural science, or other elective sciences.

The reviewing committee of The Commission on the Reorganization of Secondary Education, after three years of work in formulating and revising a report, issued a statement of the Cardinal Principles of Secondary Education. This was published in 1918 by the United States Bureau of Education as Bulletin No. 35, and in it the committee has set forth the "fundamental principles that would be most helpful in directing secondary education."

The Committee states in its definition of the goal of education in a democracy that "The purpose of democracy is so to organize society that each member may develop his personality primarily through activities designed for the well-being of his fellow members and of society as a whole." Education is

necessary to achieve this end. "Consequently, education in a democracy, both within and without the school, should develop in each individual the knowledge, interests, ideals, habits, and powers whereby he will find his place and use that place to shape both himself and society toward ever nobler ends."
The main objectives of education, obtained by analyzing the activities of the individual, in a democratic society are classified by the committee as follows: 1. Health. 2. Command of fundamental processes. 3. Worthy home-membership. 4. Vocation. 5. Citizenship. 6. Worthy use of leisure. 7. Ethical character.

The next constructive step in the reorganization movement affecting physics directly was the issuing of a report by the Committee on Science of the Commission on the Reorganization of Secondary Education, which was published by the United States Bureau of Education in 1920 as Bulletin No. 26, under the caption Reorganization of Science in Secondary Schools - A Report of the Commission on the Reorganization of Secondary Education, Appointed by the National Education Association. It brought to a conclusion several years of study of the problem and is in essential agreement with the seven Cardinal Principles of Secondary Education, and the outline of objectives and working principles set forth by the Reviewing Committee.

Since this Report stands today, as it has done during the past decade, as the basis of reference for all efforts to improve the teaching of physics in general in the high school, the preface, containing a clear statement of the aims and methods of the committee, is here reproduced in full.

"The committee on science of the Commission on the Reorganization of Secondary Education has carried on its work by means of discussions, correspondence, and formulation of preliminary reports for over seven years. The discussion of preliminary reports by groups, committees, and at meetings of science teachers has revealed progressive work already under way and has led to the trial of preliminary recommendations. Some of the improvements that the committee sought to effect have already been adopted by many of the best schools. The full report herein presented, formulated through this procedure, incorporates practices that have proved most useful. It asks for only those features of reorganization that have been found to work well, or which by a fair amount of trial promise improvements. Further experiments with new courses in science, or with the readjustment of older courses, may make desirable and necessary a revision of the report before many years have passed.

"The report embodies contributions and criticisms of more than 50 science teachers and administrative officers. It does not include every proposal, as many such proposals are not fully approved by others. Some members of subcommittees have been unable to send criticisms of the full report, but because of their previous important work on subcommittees their names are included in the list of members.

"The report has been approved by the reviewing committee of the Commission on the Reorganization of Secondary Education. This approval does not commit every member of the reviewing committee individually to every statement and every implied educational doctrine. It does, however, mean essential agreement with the general recommendations.

Otis W. Caldwell,
Chairman Committee on Science.
Clarence D. Kingsley,
Chairman of the Commission."

The report is divided into two parts. Part one deals with the entire field of science education under three main divisions:

I. "The general aims and purposes of secondary science instruction.

II. "General principles governing the selection of material and its presentation.

III. "Science sequences recommended for various conditions."

Part two treats the principal courses in science separately.

The Committee in part one stresses the need of science reorganization by pointing out the evidences of "variation of purposes for which sciences are taught, the increasing number of sciences offered, the development of intensive specialization within various sciences, the lack of sequence in the order in which they are frequently given, the wide variation in methods and contents"; and proceeds to define the general aims and purposes of science teaching. These are stated with reference to the main objectives of education, also with reference to the

specific values obtainable from science study. The committee firmly believes that science instruction should materially contribute to the realization of six of the seven main objectives of education, omitting only command of fundamental processes. A detailed statement is made of the specific values that science study should secure by the development of interests, habits, and abilities; in teaching useful methods of solving problems; in stimulating to purposeful activities; in information; and in cultural and aesthetic development.

As given in the report, the organization of science instruction should rest upon the following principles:

a. "Self activity is a law of growth.

b. "Interest secures attention and makes self activity possible.

c. "Interest, to be sustained, must rest on the perception of the worthwhileness to the individual of the purpose sought.

d. "A usable question, problem, project, or topic involves a purpose, the immediate or future worthwhileness of which is recognized by the individual and by the class."

A recommendation of a sequence of science courses for various types of schools, ranging from large to small, is made. In general, the same logical sequence is to be followed, and calls for general science in the first year, biological science in the second year, and chemistry and physics as differentiated elective courses in the third and fourth years.

The section devoted to physics in part two opens with a statement of the reasons for reorganization of the subject. Six

points are emphasized, namely, the failure of content and methods of presentation to make a vital appeal to pupils; the neglect of the interest of pupils and the laws of learning; the assumption that a principle is readily understood if stated clearly and illustrated by a few examples; the failure to correlate properly the class and laboratory work; the failure of traditional courses to interpret the higher type of vocations in which physics is fundamental; and the fact that many schools have noted marked improvements in interest and outcome when certain changes were made.

Physics, as with science in general, should contribute to the realization of six of the seven main objectives of education. No definite syllabus is recommended, leaving this to the teachers who can best adjust it to the varying needs of the pupils. In this connection the report says, "The subject matter should be made simple enough to be clearly comprehended by the pupils. It should be of fairly obvious utility, from the pupil's standpoint, in the accomplishment of some worthy purpose. It must have the greatest number of elements in common with everyday situations, within the experience, interest, and knowledge of the pupils, or in common with the situations in which they may reasonably be expected to take part when they have become adults."

This report has been for a decade and remains today of tremendous worth chiefly because of the scientific and comprehensive manner in which it has dealt with the problems of science instruction. Just as the Committee of Ten in 1893 had crystallized science teaching ideas from the viewpoint of the college, so did this report of the Committee on Science of the Commission

on the Reorganization of Secondary Education try, and succeed admirably in the attempt, to sum up the prevailing opinions on the same problem from the secondary school viewpoint.

CHAPTER XVII

CONTENT AND METHOD OF SCIENCE TEACHING ARE STUDIED WITH THE AID OF EDUCATIONAL TECHNIQUE

The third decade of the twentieth century and continuing into the fourth have witnessed many investigations in practically all subjects in the field of secondary education to determine scientifically how much of the subject material being taught is really worthwhile from the standpoint of the pupil's ability to learn, and whether the most efficient methods of instruction are being used.

As early as 1911 Dr. Charles H. Judd in an address[1] before the Central Association of Science and Mathematics Teachers had questioned the content and organization of high school science courses. He urged that scientific investigation be applied to these vital questions, saying, "Science teachers are not willing to examine and discuss the needs of their students as a primary consideration in the organization of their course. Science has a kind of inflexible logic of its own in the mind of the mature teacher, has a kind of coherency in organization that is so attractive that to break down this ideal arrangement in any wise or to criticise the typical arrangement of science material in any wise is very repugnant for the true scientist."

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[1] School Science and Mathematics 12: 87-98. 1912.

He further says, "Let us present science, says the specialist, in the order known to be the final order. I repeat, that you cannot do it, and it is my plea as a student of education; a plea to you who are specialists in sciences; let us get together and see that this material is in some fashion recognized, and that you make it your business to study the students." In his book, Psychology of High School Subjects, published in 1915 he repeats his assertions made in 1911 and adds, "the value of science teaching is on every hand, seriously called into question" since the practical application of science by students is, in general, very meager.

In Science Teaching by George R. Twiss, published in 1917, the author suggests that the subject matter ought to be reorganized about the larger and more general principles, and that topics too difficult for, or outside the realm of experience of, high school pupils be omitted. As to method he claims that science teaching has failed to arouse and to hold the interest of pupils. Both Judd and Twiss emphasized the need of starting the teaching of principles with problematic concrete situations that arouse and hold the interest of the pupils. Criticism of the laboratory course, of the recitation methods, and of other phases of physics teaching appeared in periodicals throughout the country, and scientific investigations were set afoot which more or less solved many of the difficulties pointed out.

Along with this movement to improve science teaching there has developed during the past two decades a new field of educational endeavor, namely, the science of testing and measuring educational results, learning abilities, and other features of education.

We find that this educational technique was gradually finding its way into the scientific investigations that were being made in the field of science teaching. In January, 1921, Charles W. Finley of Columbia University published[2] the results of a study he had made in trying to determine what part of the content of science should be taught to appeal to children's interests. The article served to stimulate others to make similar investigations.

Earl R. Glenn, also of Columbia, during the years 1921-1923 published several articles[3] showing the results of studies made of the conventional examinations in chemistry and physics versus the new types of tests. The purpose of such studies was to secure a basis for more accurate and uniform evaluation of classroom teaching results.

In 1922, Arthur L. Foley of Indiana University, reported[4] the results of a series of tests given to students of a number of Indiana colleges. The purpose of the tests was to determine if college students who had had high school physics secured better grades in college physics than did those students who had not had high school physics. The results showed a slightly higher average grade for the first group.

Another study[5] that aroused much interest was that made in a Michigan high school by E. W. Kiebler and Clifford Woody to determine the relative effectiveness of the demonstration and individual laboratory methods in teaching physics. Both temporary

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[2] School Science and Mathematics 21: 1-24. 1921.

[3] School Science and Mathematics 21: 666-670. 1921; 21: 746-756. 1921; 23: 459-470. 1923.

[4] School Science and Mathematics 22: 601-612. 1922.

[5] Journal of Educational Research Vol. 7 PP 50-58 1923.

and permanent knowledge were tested, also knowledge of how to apply principles and technique learned in attacking new problems. In general, the demonstration method was found as good as, if not superior to, the laboratory method.

Dr. Powers, of Columbia University, made a significant study[6] in chemistry teaching, the results of which were published in 1924. He concludes that the task set for high school students in chemistry is beyond their accomplishment, and that they gain no mastery over a large amount of the materials of instruction.

J. M. Hughes, of Northwestern University, published in the March and April numbers of the School Review for 1925 the results of an investigation to determine the effect of the pupil's intelligence and the teacher's training on the achievement in the study of physics. In regard to the teacher's training it was found that pupils taught by teachers who had emphasized physics in their training had a distinct advantage over those taught by teachers of less training.

In 1926 J. M. Hughes reported[7] the results of another study; namely, of the content of the high school physics course obtained through the answers from one hundred teachers throughout the country. The fact that ninety-four out of the one hundred teachers used the same three textbooks; that these three textbooks covered practically the same identical topics and experimental and pictorial illustrative materials, with equal spatial

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[6] Powers, S. R. A Diagnostic Study of the Subject Matter of High School Chemistry.

[7] School Science and Mathematics 26:619-23. 1926.

allotments; and that but a very small percentage omitted any considerable amount of the text, or required collateral reading, indicated very clearly the great similarity in the content of physics courses throughout the entire country. The writer suggests that this content is too greatly dominated by inherited tradition, and urges that the status of physics teaching needs to undergo a profound change.

In view of the findings in Missouri in 1925-26 that 90 per cent of physics teachers followed the exact organization of the large divisions of subject matter as they appeared in the textbooks, and that an even larger percentage followed the exact sequence of these large divisions through the books, C. J. Peters, of the University High School at Columbia, Missouri, made a study in 1927 of the achievement of pupils under two conditions; first, when taught under the customary organization of subject matter as presented in the average textbook in which principles and laws precede the practical applications of the same, and second, when taught under reorganized subject matter which first emphasizes the application of the fundamental principle, and later states the generalization or law. His results[8] indicate that achievement was much greater when taught by the reorganized subject matter, both in the grasping of the fundamental principles, and in the applications of the same.

Dr. A. W. Hurd, of Columbia University, says in an article[9] in 1928 that he has tabulated the consensus of opinions of authoritative writers, writing from 1900-1926 as to the inade-

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8 School Science and Mathematics 27:172-82. 1927.

9 School Science and Mathematics 28:637-39. 1928.

quacies in high school science teaching, and combines them under five categories which demand the following remedies: (1) well defined aims and objectives, (2) well chosen subject matter suited to the needs of the pupils, (3) better selection and training of teachers for the particular job in hand, (4) greater responsibility and freedom of action of pupils with motivation emphasized, and (5) methods of science used to determine future changes in the course. 1900 to 1912 had seen numbers (2) and (3) emphasized, while 1913 to 1926 had seen (5), (4), and (1) receive the bulk of attention. The writer describes the value of this analysis to be in furnishing the conscientious teacher and curriculum builder a clearly defined task, namely, that of discovering by a common sense, inclusive survey, more clearly desirable aims and objectives, and the important subject materials best adapted to accomplish these aims and objectives. Teachers must be better trained, and the pupils must be made responsible parties to the learning process by being given more opportunity for individual initiative.

E. S. Obourn a few months earlier wrote[10] in connection with the effective use of practical equipment in the physics course, that such material today serves merely to illustrate without much inquiry as to its operative principle, or possibly as a demonstration piece by the instructor. To realize the greater possibilities offered by such practical equipment the writer suggests that the thorough organization of the learned subject matter be followed by concrete life situations through carefully planned applications in which the pupil manipulates, dissects and analyzes life-sized devices.

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[10] School Science and Mathematics 28:275-80. 1928.

In 1929 G. C. Muthersbaugh[11] attempted to draw up a new list of specific objectives in physics, based on usefulness, interest, and frequency of occurrence. A careful examination of the four most popular textbooks in use, four courses of study and two treatises was made to determine specific objectives in vogue at the time. Using this list as a basis for study, a new list was proposed in which all dead and obsolete material had been eliminated, and all physical theories and principles which had no connection or application with current day activities had been dropped. This list, containing 221 specific objectives, is given in the article and composes the proposed course of study in physics for senior high schools.

Another investigation[12] made in the same year was that carried on by E. W. Kiebler and F. D. Curtis, to determine the content of the laboratory course in high school physics. They attempted, first, to ascertain by examining the eight most popular laboratory manuals in use, the relative frequency with which various laboratory exercises appeared in these manuals, and second, to determine the relative importance of these experiments as judged by teachers in high schools and schools of higher learning. The findings indicated a wide diversity of opinion among both the manual authors and the teachers as to what exercises should constitute the laboratory course. The authors list in table form the various exercises and their evaluation, by means of which the reader is given the opportunity of select-

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11 School Science and Mathematics 29:943-54. 1929.

12 School Science and Mathematics 29:980-5. 1929.

ing those experiments which should constitute a rich laboratory course according to authoritative opinion.

Dr. A. W. Hurd reported[13] in April, 1930, the results of an investigation carried on at the University of Minnesota in 1928-29 to determine whether high school physics learning contributed to college physics achievement. By means of prognostic tests it was found that the average college student shows distinct outcomes from a course in high school physics, in knowledge and ability to solve problems, peculiar to the course itself. The investigation next attempted to decide whether these abilities carry over into the college course, so that he maintains his superiority. The results showed but a very slight advantage on the part of those who had had high school physics. The writer explains this by saying that whereas high school physics is concrete, with a profusion of life-like applications and photographs, the college course is abstract, deductive, and full of formulas and problems. Their treatment of physics is so different that the study of one does not help greatly in the study of the other.

The Bulletin of High Points for September, 1930, published in the interests of the New York City high schools, contains a very interesting article on 'Why Girls Should Study Physics' by J. W. McCormack of the Jamaica High School. In view of the fact that 300 boys and only 41 girls were enrolled in the physics course of the Jamaica High School for the February-June, 1930 period, this writer undertakes to show, by referring to numerous everyday activities, that the average girl has just as great a

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13 School and Society 31:468-70. April 5, 1930.

need of a practical knowledge of scientific principles as does the average boy.

Dr. A. W. Hurd's investigation on the inadequacies and suggested remedies in high school science teaching has already been mentioned. In 1930 Dr. Hurd reported[14] a second investigation of the same problem as it related especially to physics teaching. Selection of content for a new course in physics was based on four ultimate objectives which are condensations of the seven cardinal principles, namely, (1) health, (2) vocation, (3) avocation, and (4) social. The immediate objectives in the selection of content were of four kinds: (1) knowledge, (2) appreciations or attitudes, (3) techniques, and (4) habits and skills. The investigation shows that the present year's course in physics contains too much content if greater achievement is to be expected. Three needs for reorganization of physics teaching are emphasized: first, new discoveries in the content of physics; second, new discoveries of educational investigations; and third, the fact that the school population has changed in type.

The above investigations are but a few of the many that have been made during the last decade. They will help to illustrate the large variety of elements in physics teaching that are now receiving thorough study in the most progressive scientific manner. These investigations can, in the main, be classified as of two general types; first, content studies, or studies to determine the kind and amount of curriculum material that should be used; and second, learning studies, or studies to find out

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[14] School Science and Mathematics 30:539-45. 1930.

what part and how much of the material presented in the course of instruction is learned by the pupil. Their correct solution will realize greater economy of time and effort, together with superior results.

CHAPTER XVIII

THE "NEW PHYSICS" AND MODERN PHYSICS TEXTBOOKS

For several years past, as a direct result of the many technical investigations being carried on, there has been much discussion about the "new physics". By this phrase is usually meant the movement in physics teaching to gather the content of the physics course from the physics of actual daily life. Although the laboratory manuals still adhere in large part to the old method of presenting experiments which measure problems disembodied from the daily life of the pupil, there has recently been some worthwhile attempts toward developing experiments which deal with real objects and real problems. However, it has been left mainly to the textbooks to embody this "new physics" into the physics course.

To find to what extent this "new physics" movement has entered into the physics teaching of the country it was decided to investigate what the large high schools are doing in physics. The small high school is usually circumscribed in its efforts to differentiate its physics program according to the needs of the different groups of pupils, since its population usually

permits of only one class in physics. It is only natural under such conditions that the aims of the teaching must necessarily center about those pupils who plan to enter college. The needs of the others are usually subordinated to the needs of the college group.

But this need not be true of the large high schools which have a population which demands several classes in physics. These schools should be able to offer various courses in physics which especially stress those phases of physical principles as apply to General Physics, Industrial Physics, Household Physics, Applied Mechanics, Electricity, and other present day vocations, in addition to offering the customary course that prepares mainly for college.

In accordance with this idea, in the early part of 1931 the writer sent out a questionnaire to high schools in all cities of the United States which had a population exceeding 200,000. Forty-one copies of the questionnaire were sent out and twenty-eight replies were received, from twenty different states. The questionnaire listed five physics courses - College Preparatory, Industrial, Household, Applied Mechanics, and General. The high schools were requested to check those courses given, to state the text used, number of recitation and laboratory periods per week and length of same, length of course, and relative amount of problem solving required.

The replies showed that three schools were offering the College Preparatory course only, and that two of the three schools used Millikan, Gale, and Pyle's Elements of Physics,

and the other used Fuller, Brownlee, and Baker's Elementary Principles of Physics. Sixteen schools reported that they offered the General course only. Five of these used Millikan, Gale, and Pyle's text; four used Dull's Modern Physics; three used Black and Davis' Practical Physics; and three used Fuller, Brownlee, and Baker's text.

Nine schools stated they each offered two or more of the five courses listed, different texts being used for each separate course usually. The above four texts divided honors about equally in these nine schools in the College Preparatory and General courses. Five of these nine schools reported they offered one or more of the Industrial, Household, or Applied Mechanics courses, and usually specified special texts emphasizing these fields of endeavor.

As to the length of the courses, number and length of recitation and laboratory periods, and relative amount of problem solving, it was found that the College Preparatory and General Courses called for one full year in all cases but one. The College Preparatory courses averaged 4.0 recitation and 2.3 laboratory periods per week of an average length of 45 minutes. The average number of experiments per year was 32. Out of ten schools, five specified a large amount of problem solving, and five a medium amount. The General courses averaged 3.2 recitation and 2.8 laboratory periods per week of an average length of 45 minutes. The average number of experiments was 40. Out of twenty schools specifying, five required a large amount of problem solving; ten a medium amount; and five a small amount. On the basis of a year's work the courses other than College Prepara-

tory and General averaged 3.3 recitation and 2.6 laboratory 45 minute periods per week with an average of 34 experiments. Eight specified a medium amount of problem solving and three a small amount.

The results would tend to show that no one textbook is favored either for the College Preparatory course or for the General course, about the same number of schools using one book as another. Likewise, no distinct difference is noted in the relative amount of time devoted to recitation and laboratory work, the College Preparatory course usually calling for a somewhat higher amount of the former and less of the latter than the General course or other courses. The College Preparatory course evidently calls for more problem solving than the General course, which in turn calls for more than the other courses. The General course requires a little more laboratory work than either the College Preparatory course or the other courses.

In general the results indicate that both the College Preparatory and General courses aim to give a thorough training in physics, sufficient for entrance to college, and at the same time emphasizing as much as possible every day applications. From the footnotes attached to many of the answers it is quite evident that there is great interest in many high schools to establish the newer courses - those dealing entirely with popular vocational branches of physics, such as Applied Electricity, D. C. Electricity, A. C. Electricity, Mechanics, Radio Measurements, and Aeronautics. The next few years should see the introduction of many of these special courses into numerous large high schools, especially in industrial centers.

Since the results of the questionnaire indicate that the large high schools of the country practically limit their choice to four textbooks, a comparison of these books will show what is the prevailing attitude of the textbook writers toward physics teaching at the present time. These four books can be roughly divided into two classes. The first emphasizes the type of work that is especially adapted for training the pupil toward college entrance. Millikan, Gale, and Pyle's Elements of Physics (1927) and Black and Davis' New Practical Physics (1929) represent this class. The second class while covering the essentials necessary for admission to college lays especial emphasis on practical applications of the principles of physics. Dull's Modern Physics (1929) and Fuller, Brownlee, and Baker's Elementary Principles of Physics (1925) represent this class.

These four textbooks have all attempted to 'vitalize' the teaching of physics by excluding the more abstract subjects and so presenting the remaining material as to appeal to the everyday interests of boys and girls. Although all the claims found in their prefaces are frequently not realized, it can be said that these texts have gone a long way toward putting this subject in a more favorable light from the standpoint of the pupil's interests and needs.

Millikan, Gale, and Pyle write in their preface that "Their chief aim from the beginning has been 'to present elementary physics in such a way as to stimulate the pupil to do some thinking on his own account about the hows and the whys of the physical world in which he lives.'" They claim to have included only such material as touches closely the everyday life of the average pupil,

and have tried to avoid the encyclopedic array of heterogeneous facts. The book is divided into two parts, the shorter form being in larger print and representing "the indispensable backbone" of a physics course where a minimum amount of time is available. The importance of problem work in this book, even in the shorter course, is readily perceived by the statement that "--- the problems, the heart of any course, have been especially chosen and especially tested for such use." The longer course consists of the large print plus additional smaller print and has "an abundance of additional problems in the Appendix." As a means of arousing pupil interest the authors have included "an incidental picture course on the history of physics." This picture course includes ninety-nine full-page illustrations of outstanding industrial appliances, and the heroes of physics, with rather elaborate explanatory legends. Its purpose is to incidentally present a large number of fascinating facts and developments which will tend to arrest the pupil's attention and to stimulate him to further studies along scientific lines.

Black and Davis' text, while perhaps not quite as mathematical as Millikan, Gale, and Pyle's still includes a large amount of problem solving.

The preface states, "Throughout this book we have stressed the applications of physical principles which we see in our daily lives rather than the subtleties of molecular physics and atomic structure. Our experience shows that students derive great satisfaction from detecting about them instinctively and habitually applications of a science which they have studied or are studying."

The authors have tried to "set practical rather than artificial problems and have minimized the arithmetical drudgery involved in solving them." The subject matter has been brought upto-date so as to include the basic principles of aviation, radio, television, and colored and talking pictures.

Charles E. Dull's text is an excellent example of that school of advanced thought that believes physics should be above everything else a practical subject. The preface says, "Few subjects touch the student's life more closely than elementary physics. No subject is better fitted to develop the reasoning powers, or to cultivate that uncommon faculty known as 'common sense'. From the time the pupil opens the water faucet in the morning until he snaps off the electric light upon retiring, he is constantly applying or observing some of the principles of physics." The author states he has tried to keep in mind the pupil's point of view, and to use such simple language as to make those topics ordinarily difficult understood. To show that even this author does not believe mathematics can be entirely eliminated we read, "Many thought-provoking questions are included, and the number of problems is so great that few pupils will find time to do them all." He has omitted many of the more difficult formulas since "they look more complicated and seem more difficult than the problems themselves."

In Fuller, Brownlee, and Baker's text we find a rather radical departure from the traditional order of topics. The authors state in the preface that the usual order often leads to loss of interest and to a feeling of dismay at such difficult work too early in the course. They have rearranged the material so as to

present a 'cycle' order, i.e., the observational parts of each topic are studied early in the course and involve only simple relations and problems. The more difficult parts of each topic come later in the course when the pupil's earlier experience with the science and some gain in maturity will enable him to better handle these difficult parts. The mechanics of solids with its abstract mathematical characteristics is placed late in the book. The authors believe "that students lose interest in Physics because of the formal presentation of the subject. There have been too many new terms, abstract concepts, and laborious calculations. The attempt has been made in this book to bring the subject to the student in language that he can readily understand and in steps which progress with his mental development."

One cannot examine any one of the textbooks described without being convinced that they have tried, and with a fair degree of success, to make the applications of physics which are so common, understandable to the pupils of our physics courses. That there is still a large field for improvement is indicated by the various methods used by the different authors, and by the results of the many investigations which have been, and still are being, made.

CHAPTER XIX

SUMMARY

In concluding this story of the development and trend of physics teaching in the secondary schools, the motivating element underlying the methods and aims of each period will be especially noted, with the hope that the reader will thereby gain a more connected view of the story.

A general survey of science from the time of Aristotle up to and including present tendencies will impress the reader with the fact that one main force has been actuating each successive stage in the growth of physics teaching, namely, the desire to make a knowledge of natural phenomena serve the needs of mankind.

The great contribution to world civilization made by the Greeks was along the lines of literature and philosophy rather than along scientific lines. Yet, by observation and speculation the scholars of Greece tried to satisfy the craving of the people for an understanding of their circumscribed universe by finding intellectual answers to questions regarding the shape, size and motion of the earth and the heavenly bodies, and the nature of matter - questions that have perplexed mankind from the beginning. Their answers, sometimes correct, but oftener

wrong - gave the people of those days a more secure feeling - through obliterating the unexplained, which is always shrouded in a cloak of mystery - and hence of fear.

The Romans were a practical people, bent upon organizing and executing practical undertakings, and were little interested in theoretical discussion. Inherited Greek theories satisfied their wants in the field of science and they made practically no attempts to disrupt these theories.

The dominant feature of the Middle Ages was the intolerant attitude of religion toward inquiry of any sort. The church believed that the enforcement of a moral life was endangered by such inquiry, and science continued on an Aristotelian basis.

From the twelfth century on, mankind began to gradually change the character of his thinking, to the disintegration of the Mediaeval System. The Revival of Learning throughout Western Europe and the Italian Renaissance signify the beginning of this modern scientific spirit with its critical, questioning attitude. The doctrines and practices of the Mediaeval Church began to be questioned. Mankind's yearning for a more satisfying explanation of the natural phenomena surrounding him was awakened. Greek science was gradually rejected and a new era, opened by Galileo, dawned upon the world. The explanation of mysticism, good and evil spirits, and the interpretation of natural phenomena as manifestations of the Divine will had for centuries stagnated scientific inquiry, but it had nevertheless a steadying influence upon the peoples of the times since it offered an explanation for these mysteries in a more or less simple and, for the thought of the time, satisfactory manner. Mass domination had made such

thinking possible, but with the advent of individual thinking the old explanations were found wanting, and more satisfying reasons were sought.

By the time that natural philosophy was introduced into the schools, natural phenomena were found to be most satisfactorily explained by scientific laws. From that period until the present day this scientific interpretation of natural phenomena has persisted, and each succeeding change in physics teaching has been made only that it might provide for the development of increased efficiency on the part of the individual and for the more satisfactory progress of society.

The last half of the nineteenth century with its stress on mental discipline, laboratory work, mathematical and abstract knowledge, and college preparatory aim, effectively demonstrates the expression of this belief. Mental discipline was supposed to give greater social usefulness by increasing the breadth and definiteness of the activities of those whose minds had been so trained. The laboratory work was to serve the same purpose by increased efficiency of the individual due to training in more real, lifelike experiences. Mathematical and abstract knowledge was stressed that it might advance society through the channels of pure science, and the college preparatory aim was justified by insisting that such training obtained the greatest good for the greatest number.

The end of the century with its movement away from these aims in favor of the practical application of physics knowledge to everyday life was simply a natural step as the realization dawned upon mankind that social usefulness is only reached by

so training the individual that he reaches his highest efficiency. This new conception of education invoked the theory that because of the varied natures of the individuals composing society, this training must be in terms of the individual rather than of the group. It was found that the individual must receive such practical knowledge as would fit his particular need.

The twentieth century with its enormous amount of scientific investigation has simply continued this trend to make physics teaching cater to the individual so that he might serve society best by raising his own competency to the highest possible level. These investigations have emphasized methods and materials of instruction. Today, scientific students of education are engaged in evaluating such methods and materials in terms of the Seven Cardinal Principles, trying to find those that will result in the greatest advancement of society.

APPENDIX A.

List of fundamental experiments in physics as given in Report No. 7 1884 United States Bureau of Education. Aims and Methods of the Teaching of Physics; By Professor Charles K. Wead, of the University of Michigan.

A # means fitted for laboratory work; a / involves measurement; an *, more advanced.

#/ Compare and measure lengths, volumes, and masses.
#/ Composition of forces.
Inertia.
#/ Parallel forces.
Center of gravity.
#/ Lever, inclined plane, &c.
#/ Pendulum.
* Centrifugal action.
#/ Archimedes' principle.
#/ Density and specific gravity.
Capillarity.
#/ Simple barometer.
/* Boyle's law.
Air pump experiments.
Pumps and siphon.
#/ Expansion of liquids and gases.

Properties of permanent and temporary magnets.
Magnetic curves.
Simple galvanic cell.
Effects of current on magnetic needle.
Electro-magnets.
/* Influence of resistance of conductors.
Chemical effects of current.
* Heating effects of current.
* Induction.
Telegraph and telephone.
Frictional electricity; two states.
Electrical machine; Leyden jar.
Vibration and production of waves.

Bending of compound bar.

#/ Verify fixed points of thermometer.

Conduction of heat.

#/ Temperature of mixtures of water.

/* Specific heat of a solid.

#* Latent heat of ice, steam, vapors.

Heat from friction.

* Useful forms of galvanic cells.

#/ Resonance.

Interference of sound (fork and jar).

/ Monochord.

#/ Photometer.

Reflection; plane and curved mirror.

Refraction of light.

Dispersion and spectrum.

Total reflection.

#/ Lenses; construction of image.

Combination of colors.

APPENDIX B.

The following is a list of experiments submitted by the Committee of Ten in their report to the National Educational Association in 1894:

GENERAL PROPERTIES OF MATTER.

1. Find the volume, weight, and density of several solids, as wood, iron, stone, etc.

2. From the known weight of a given length of wire, calculate the length of a roll of fine wire from its weight.

3. Find the capacity of a bottle by weighing without and with water, or mercury.

4. Study the elasticity of stretching of rubber, or brass wire, and see whether the results agree with the laws.

5. Determine the elasticity of bending of wood as to length, breadth, and thickness, and see whether the results agree with the laws.

6. Find the co-ordinates of a given curve drawn on co-ordinate paper and plot a curve from given co-ordinates.

Mechanics of Fluids.

1. Pressure of liquids as to direction and depth.

2. Compressibility of air - Verify Mariotte's Law.

3. The buoyant force of a liquid by weighing in water and weighing the displaced water.

4. Relation of the volume of a regular solid to loss of weight in water.

5. Find the relative density of a number of substances heavier than water.

6. Relative density of a substance lighter than water, by use of a sinker.

7. Relative density of wood by flotation.

8. Relative density of a liquid:

(a) By weighing a substance in the liquid and in water;

(b) By weighing the liquid and water in the same vessel, separately;

(c) By Hare's method of balanced columns raised by exhaustion.

9. Relative density of air by exhaustion from a bottle.

10. Action of the siphon. By connecting two vessels of water by a rubber tube, determine the conditions causing the flow.

11. Find the weight of a column of mercury in a tube, per centimeter, by measuring its length, and weighing the mercury.

12. Calculate the pressure of the atmosphere by weight of a column of mercury.

Mechanics of Solids.

1. The principles of the composition and resolution of forces: by the action of three forces in the same plane and not parallel, using spring balances; also by construction, using the parallelogram of forces.

2. The law of the distances of points of application of two parallel forces from the points of application of their resultant, or equivalent.

3. Law of the moments of two parallel forces acting on a body.

4. Movements about a fixed point of any number of parallel forces in the same plane.

5. Movements of two sets of parallel forces, or couples, in the same plane.

6. Centre of gravity of a material rod. By use of extra weights find the point where the weight of a material body acts.

7. Centre of gravity of a material triangle.

8. Comparison of masses by inertia.

9. Relation of the time of vibration of a pendulum to its length.

10. Relation of friction to pressure.

11. Work done in moving bodies up an inclined plane.

12. Relation of the acceleration of falling bodies to the moving force.

Heat.

1. Verifying the freezing-point and boiling-point of a thermometer.

2. Linear expansion of a solid.

3. Heat-capacity of a calorimeter.

4. Specific heat of a substance.

5. Latent heat of water.

6. Latent heat of steam.

7. Dew-point of the air of the room.

Sound

1. Pitch of a tuning-fork by a column of air in a vessel.

2. Relation of pitch to length in wires.

3. Relation of pitch to tension in wires.

Light

1. Photometry: relation of intensity to distance of a light.

2. Relation between the angle of incidence and the angle of reflection of light.

3. Position of images in plane mirrors.

4. Find the critical angle of water.

5. Find the critical angle of kerosene.

6. Find the focal length of a converging lens.

7. Size and position of real images in a converging lens.

8. Size and position of the virtual images in a converging lens.

Electricity.

1. Mapping the lines of magnetic force for a bar-magnet.

2. Constancy of the two-fluid Daniell's cell, and change of weight of the elements of the cell.

3. Electrical resistance, as to length and cross-section of conductors.

4. Measurement of resistance by substitution.

5. Measurement of resistance by Wheatstone's bridge.

6. Electromotive force of different metals.

7. Electromotive force of cells as to size and number, placing them in opposition.

8. Method of connecting cells with reference to external resistance. Compute the current-strength, using the formula $C = \frac{E}{R+r}$

9. Law of induced currents as to duration and direction.

APPENDIX C.

List of experiments suggested by Professor E.H. Hall in the report of the Committee on College Entrance Requirements, 1899.

FIRST PART.

(Recommended, but not to be counted)

A. Measurement of a straight line.

B. Lines of the right triangle and the circle.

C. Area of an oblique parallelogram.

D. Volume of a rectangular body by displacement of water.

Mechanics and Hydrostatics.

1. Weight of unit volume of a substance.

2. Lifting effect of water upon a body entirely immersed in it.

3. Specific gravity of a solid body that will sink in water.

4. Specific gravity of a block of wood by use of a sinker.

5. Weight of water displaced by a floating body.

6. Specific gravity by flotation method.

7. Specific gravity of a liquid: two methods.

8. The straight lever; first class.

9. Centre of gravity and weight of a lever.

10. Levers of the second and third classes.

11. Force exerted at the fulcrum of a lever.

12. Errors of a spring balance.

13. Parallelogram of forces.

14. Friction between solid bodies (on a level).

15. Coefficient of friction (by sliding on incline).

Light.

16. Use of Rumford photometer.

17. Images in a plane mirror.

18. Images formed by a convex cylindrical mirror.

19. Images formed by a concave cylindrical mirror.

20. Index of refraction of glass.

21. Index of refraction of water.

22. Focal length of converging lens.

23. Conjugate foci of a lens.

24. Shape and size of a real image formed by a lens.

25. Virtual image formed by a lens.

SECOND PART.

Mechanics.

26. Breaking strength of a wire.

27. Comparison of wires in breaking tests.

28. Elasticity: stretching.

29. Elasticity: bending; effect of varying loads.

30. Elasticity: bending; effect of varying dimensions.

31. Elasticity: twisting.

32. Specific gravity of a liquid by balancing columns.

33. Compressibility of air; Boyle's law.

34. Density of Air.

35. Four forces at right angles in one plane.

36. Comparison of masses by acceleration test.

37. Action and reaction: elastic collision.

38. Elastic collision continued: inelastic collision.

Heat.

39. Testing a mercury thermometer.

40. Linear expansion of a solid.

41. Increase of pressure of a gas heated at constant volume.

42. Increase of volume of a gas heated at constant pressure.

43. Specific heat of a solid.

44. Latent heat of melting.

45. Determination of the dew-point.

46. Latent heat of vaporization.

Sound

47. Velocity of sound in open air.

48. Wave-length of sound.

49. Number of vibrations of a tuning-fork.

Electricity and Magnetism.

50. Lines of force near a bar magnet.

51. Study of a single-fluid galvanic cell.

52. Study of a two-fluid galvanic cell.

53. Lines of force about a galvanoscope.

54. Resistance of wires by substitution: various lengths.

55. Resistance of wires by substitution: cross-section and multiple arc.

56. Resistance by Wheatstone's bridge: specific resistance of copper.

57. Temperature coefficient of resistance in copper.

58. Battery resistance.

59. Putting together the parts of a telegraph key and sounder.

60. Putting together the parts of a small motor.

61. Putting together the parts of a small dynamo.

APPENDIX D.

Definition of the unit in physics, as drawn up by the National Commission on the Teaching of Elementary Physics, and adopted by the North Central Association of Colleges and Secondary Schools in 1908.

The Definition of the Unit in Physics.

1. "The unit in physics consists of at least one hundred and eighty periods of forty-five minutes each (equal to 135 hours) of assigned work. Two periods of laboratory work count as one of assigned work.

2. "The work consists of three closely related parts; namely, class work, lecture-demonstration work, and laboratory work. At least one-fourth of the time shall be devoted to laboratory work.

3. "It is very essential that double periods be arranged for laboratory work.

4. "The class work includes the study of at least one standard text.

5. "In the laboratory, each student shall perform at least thirty individual experiments, and keep a careful notebook record of them. Twenty of these experiments

must be quantitative; each of these must illustrate an important physical principle which is one of the starred topics in the syllabus of required topics, and no two must illustrate the same principle.

6. "In the class work the student must be drilled to an understanding of the use of the general principles which make up the required syllabus. He must be able to apply these principles intelligently to the solution of simple, practical, concrete problems.

7. "Examinations will be framed to test the student's understanding of and ability to use the general principles in the required syllabus, as indicated in 6.

8. "The teacher is not expected to follow the order of topics in the syllabus unless he wishes to do so."

APPENDIX E.

Syllabus of Required Topics Reported by the National Commission on the Teaching of Elementary Physics, and adopted by the North Central Association of Colleges and Secondary Schools in 1908.

Syllabus of Required Topics.

1. Weight, center of gravity.

2. Density.

3. Parallelogram of forces.

4. Atmospheric pressure; barometer.

5. Boyle's Law.

6. Pressure due to gravity in liquids with a free surface; varying depth, density, and shape of vessel.

7. Buoyancy; Archimedes' principle.

8. Pascal's law; hydraulic press.

9. Work as force times distance, and its measurement in foot-pounds and gram-centimeters.

10. Energy measured by work.

11. Law of machines: work obtained not greater than work put in; Efficiency.

12. Inclined plane.

13. Pulleys, wheel and axle.

14. Measurement of moments by the product of force times arm; Levers.

15. Thermometers: Fahrenheit and Centigrade scales.

16. Heat quantity and its measurement in gram calories.

17. Specific heat.

18. Evaporation; heat of vaporization of water.

19. Dew point; clouds and rain.

20. Fusion and solidification; heat of fusion.

21. Heat transference by conduction and convection.

22. Heat transference by radiation.

23. Qualitative description of the transfer of energy by waves.

24. Wave length and period of waves.

25. Sound originates at a vibrating body and is transmitted by waves in air.

26. Pitch and period of sound.

27. Relation between the wave length of a tone and the length of a string or organ pipe.

28. Resonance.

29. Beats.

30. Rectilinear propagation of light; pin-hole camera.

31. Reflection and its laws; image in a plane mirror.

32. Refraction, and its use in lenses; the eye, the camera.

33. Prisms and dispersion.

34. Velocity of light.

35. Magnetic attractions and repulsions.

36. Field of force about a magnet.

37. The earth a magnet; compass.

38. Electricity by friction.

39. Conductors and insulators.

40. Simple galvanic cell.

41. Electrolysis; definition of the Ampère.

42. Heating effects; resistance; definition of the Ohm.

43. Ohm's law; a definition of the volt.

44. Magnetic field about a current; electromagneto.

45. Electromagnetic induction.

46. Simple alternating current dynamo of one loop.

47. Electromagnetic induction by breaking a circuit; primary and secondary.

48. Conservation of Energy.

APPENDIX F.

List of Experiments Issued by the College Entrance Examination Board to Accompany its Definition of the Physics Unit Adopted in 1910.

Mechanics.

1. Weight of unit volume of a substance, prism or cylinder.

2. Principle of Archimedes.

3. Specific gravity of a solid body that will sink in water.

4. Specific gravity of a liquid, two methods (bottle and displacement methods); or,

5. Specific gravity of a liquid by balancing columns.

6. Boyle's Law.

7. Density of Air.

8. Hooke's Law.

9. Strength of material.

10. The straight lever, principle of moments.

11. Center of gravity and weight of a lever.

12. Parallelogram of forces.

13. Four forces at right angles in one plane.

14. Coefficient of friction between solid bodies - on a level and by sliding on an incline.

15. Efficiency test of some elementary machine, either pulley, inclined plane, or wheel and axle.

16. Laws of the pendulum.

17. Laws of accelerated motion.

Heat.

18. The mercury thermometer: relation between pressure of steam and its temperature.

19. Linear expansion of a solid.

20. Increase of pressure of a gas heated at constant volume; or,

21. Increase of volume of a gas heated at constant pressure.

22. Heat of fusion of ice.

23. Cooling curve through change of state (during solidification).

24. Heat of Vaporization of Water.

25. Determination of the dew point.

26. Specific heat of a solid.

<u>Sound.</u>

27. Velocity of sound.

28. Wave length of sound.

29. Number of vibrations of a tuning fork.

<u>Light.</u>

30. Use of photometer.

31. Images in a plane mirror.

32. Images formed by a convex mirror.

33. Images formed by a concave mirror.

34. Index of refraction of glass;

or,

35. Index of refraction of water.

36. Focal length and conjugate of a converging lens.

37. Shape and size of a real image formed by a lens.

38. Magnifying power of a lens.

39. Construction of model of telescope or compound microscope.

Magnetism and Electricity.

40. Study of magnetic field.

41. Magnetic induction.

42. Study of a single fluid voltaic cell.

43. Study of a two-fluid voltaic cell.

44. Magnetic effect on an electric current.

45. Electrolysis.

46. Laws of electrical resistance of wires; various lengths, cross-section, and in parallel.

47. Resistance measured by volt-ammeter method.

48. Resistance measured by Wheatstone's bridge.

49. Battery resistance - combination of cells.

50. Study of induced currents.

51. Power or efficiency test of a small electric motor.

BIBLIOGRAPHY

BOOKS OF GENERAL REFERENCE

Brown, Elmer E. The Making of Our Middle Schools. New York: Longmans, Green & Company. 1903.

Cajori, Florian. The Early Mathematical Sciences in North and South America. Boston: Richard G. Badger. 1928.

Cubberley, Ellwood P. The History of Education. Boston: Houghton Mifflin Company. 1920.

Curtis, Francis D. Investigations in the Teaching of Science. Philadelphia: P. Blakiston's Son & Company. 1926.

Grizzell, E. D. Origin and Development of the High School in New England Before 1865. New York: The Macmillan Company. 1923.

Inglis, Alexander Principles of Secondary Education. Boston: Houghton Mifflin Company. 1918.

Judd, Charles H. Psychology of High School Subjects. New York: Ginn & Company. 1915.

Mann, C. Riborg. The Teaching of Physics. New York: The Macmillan Company. 1912.

Meriwether, Colyer. Our Colonial Curriculum 1607-1776. Washington, D.C.: Capital Publishing Company. 1907.

Powers, Samuel R. A Diagnostic Study of the Subject Matter of High School Chemistry. New York: Teachers College, Columbia University. 1924.

Rusk, Rogers D. How To Teach Physics. Philadelphia: J. B. Lippincott Company. 1923.

Smith, A. and Hall, E. H. Teaching of Chemistry and Physics. New York: Longmans, Green & Company. 1902.

Twiss, G. R. Science Teaching. New York: The Macmillan Company. 1917.

BULLETINS, REPORTS, AND THESES

American Federation of Teachers of the Mathematical and Natural Sciences. Report of the Annual Meeting by E. R. Smith. School Science and Mathematics 12:250-252. 1912.

Bibliography of Science Teaching in Secondary Schools. Compiled by E. R. Glenn. Bulletin 13, 1925. U. S. Bureau of Education.

Bibliography of Science Teaching References. U. S. Bureau of Education. No. 29728. May, 1925 and February, 1929.

Cardinal Principles of Secondary Education. A Report of the Commission on the Reorganization of Secondary Education, appointed by the National Education Association. Bulletin 35, 1918. U. S. Bureau of Education.

Central Association of Science and Mathematics Teachers. Report of Physics Section, November 26, 1908. School Science and Mathematics. February, 1909.

____________ Report of Twelfth Annual Meeting. School Science and Mathematics 13:165-168. 1913.

____________ Report of Physics Section. School Science and Mathematics 13:258-259. 1913.

Clarke, Frank Wigglesworth. A Report on the Teaching of Chemistry and Physics in the United States. Report No. 6, 1880. U. S. Bureau of Education.

College Entrance. Preliminary Report of the Committee on College Entrance Requirements. School Review, Vol. 4 No. 6:341. June, 1896.

__________ Report of the Committee on College Entrance Requirements. Proceedings of the National Educational Association. 1899.

__________ Seventh Annual Report of the Secretary. Educational Review 34: October, 1907.

__________ College Entrance Examination Board. Document No. 48. December 1, 1910.

__________ New Program of Entrance and College Requirements Adopted by the Faculty of the University of Chicago. New Entrance Requirements to be in force October 1, 1911.

Commission on Accredited Schools and Colleges of the North Central Association of Colleges and Secondary Schools. Report for 1910, published by the Association.

Committee of Ten. Report of the Committee of Ten on Secondary School Studies; with the Reports of the Conferences Arranged by the Committee. Published for the National Educational Association by the American Book Company, New York. 1894.

Educational Miscellany and Intelligence. Barnard's American Journal of Education. Vol. 4:245. 1857.

Pathfinders of Science. Houghton Mifflin Company. 1930.

Reorganization of Science in Secondary Schools. A Report of the Commission on the Reorganization of Secondary Education, Appointed by the National Educational Association. Bulletin 26, 1920. U. S. Bureau of Education.

Sutton, T. C. A Brief History of Physics Teaching in the Secondary Schools of the United States. Master's Thesis. Battle Creek College. 1927.

Ward, David A. The History of Physics Instruction in the Secondary Schools of the United States. Manuscript. New York: Teachers College, Columbia University.

Wead, Charles K. Aims and Methods of the Teaching of Physics. Report No. 7, 1884. U. S. Bureau of Education.

Wolcott, Harry. An Analysis of Secondary School Texts in Physics in Use Since 1825. Master's Thesis. University of Minnesota. 1929.

MAGAZINE ARTICLES AND ADDRESSES

American Federation of Teachers of the Mathematical and the Natural Sciences. School Science and Mathematics. March, 1907; January, April and May, 1909.

Anderson, R. E. Adapting Within a Class the Course in Physics to the Mental Capacity of the Individual. Bulletin of High Points, New York City High Schools. 12:35-37. October 1930.

Angell, J. R. New Requirements for Entrance and Graduation at the University of Chicago. Science. June 23, 1911.

Balliet, T. M. The Influence of the Present Methods of Graduate Instruction on the Teaching in Secondary Schools. School Review. 16: April, 1908.

Bless, A. A. Teaching of Physics. School Science and Mathematics. 28:483-488. 1928.

Brownell, H. The Teaching of High School Physics. School Science and Mathematics 13:303-305. 1913.

Dana, James D. Science and Scientific Schools; Address before Alumni of Yale College, August, 1856. Barnard's American Journal of Education Vol.2:349. 1856.

Digest of Rules and Regulations of Public Schools in Cities. Barnard's American Journal of Education Vol.19:417. 1869.

Finley, Charles W. Some Studies of Children's Interests in Science Materials. School Science and Mathematics. 21:1-24. 1921.

Foley, Arthur L. The College Student's Knowledge of High School Physics. School Science and Mathematics. 22:601-612. 1922.

Gilman, D. C. Scientific Schools in Europe. Barnard's American Journal of Education. Vol. 1:315. 1855-1856.

Glenn, E. R. High School Physics in the State of Indiana. School Science and Mathematics. 13:483-491. 1913.

__________ The Conventional Examination in Chemistry and Physics versus the New Types of Tests: Part I. School Science and Mathematics. 21:666-670. 1921.

__________ The Conventional Examination in Chemistry and Physics versus the New Types of Tests: Part II. School Science and Mathematics. 21:746-756. 1921.

__________ The Conventional Examination in Chemistry and Physics versus the New Types of Tests: Part III. An Analysis of College Entrance Board Examinations in Physics. School Science and Mathematics. 23:459-470. 1923.

Hammond, Philo F. To What Extent Shall Our Present Teaching of Physics Be Guided by Vocational Work? School Science and Mathematics. 13:758-764. 1913.

Hughes, J. M. A Study of Intelligence and of the Training of Teachers as Factors Conditioning the Achievement of Pupils. School Review 33: 191-200;292-302. 1925.

Hughes, J. M. Study of the Content in High School Physics. School Science and Mathematics 26:619-623. 1926.

Hurd, A. W. Present Inadequacies and Suggested Remedies in the Teaching of High School Science. School Science and Mathematics. 28:637-639. 1928.

__________ Present Inadequacies and Suggested Remedies in the Teaching of Physics. School Science and Mathematics. 30:539-545. 1930.

__________ High School Physics Makes Small Contribution to College Physics. School and Society. 31:468-470. April 5, 1930.

Jameson, J. M. The Opportunity Now Before Teachers of Physics. School Science and Mathematics. 12:195-205; 327-335; 503-514. 1912.

Johnson, F. W. The New Harvard Entrance Requirements. Editorial Notes. School Review. June, 1911.

Jordan, Davis S. The High School Course. Popular Science Monthly. 73: July 1908.

Judd, Charles H. Meaning of Science in Secondary Schools. School Science and Mathematics. 12:87-98. 1912.

Kiebler, E. W. and Woody, C. The Individual Laboratory versus the Demonstration Method of Teaching Physics. Journal of Educational Research. 7:50-58. 1923.

Kiebler, E. W. and Curtis, F. D. Study of the Content of the Laboratory Course in High School Physics. School Science and Mathematics. 29:980-985. 1929.

Mann, C. R. Science in Civilization and Science in Education. School Review, Vol. 14: 664. November, 1906.

McCormack, J. W. Why Girls Should Study Physics. Bulletin of High Points, New York City High Schools. 12:76-78. September 1930.

Mead, G. H. Science in the High School. Discussion by Professor F. R. Moulton, Professor R. A. Millikan, and Professor C. R. Barnes.
School Review. 14:237-253. 1906.

Muthersbaugh, G. C. Objectives of a Proposed Course of Study in Physics for Senior High Schools.
School Science and Mathematics. 29:943-954. 1929.

New Movement. A New Movement Among Physics Teachers.
School Review. Vol. 14:429. June, 1906.

Obourn, E. S. Effective Use of Practical Equipment in a Physics Course. School Science and Mathematics.
28:275-280. 1928.

Peters, C. J. Evaluation of a Reorganization of the Present Core of Subject Matter in High School Physics.
School Science and Mathematics. 27:172-182. 1927.

Purpose and Organization of Physics Teaching in Secondary Schools. A Symposium. School Science and Mathematics.
January 1908; January, February, and March 1909.

Spaulding, F. B. What Knowledge (of Physics) Is of Most Worth? School Science and Mathematics. November, 1908.

Stewart, A. W. Are We Achieving Our Major Aims in Physics Teaching? Journal of Educational Research. 20:154-158. September, 1929.

Teaching of Physics; Extracts from a Report by the Educational Committee of the American Physical Society. School Science and Mathematics. 27:819-826. 1927.

Utterback, C. P. Laboratory Methods in Physics. School Science and Mathematics. 28:634-636. 1928.

Wimmer, Dr. Herman. Catechism on Methods of Teaching, translated from Diesterweg's "Almanac" (Jahrbuch) for 1855 and 1856. Barnard's American Journal of Education. Vol. 4:233. 1857.

Woodhull, John F. The Teaching of Physical Science. New York: Teachers College Record. Vol. 11. 1910. Columbia University.

TEXTBOOKS AND MANUALS

Atkinson (translated from Ganot). Natural Philosophy. 1887.

Avery, E. M. School Physics. 1895.

Black and Davis. New Practical Physics. 1929.

Brownell, H. A First Course in Physics. 1929.

Carhart and Chute. Elements of Physics. 1897.

Chute, H. N. Elementary Practical Physics (Manual). 1894.

Cloud, J. H. Principles of Physics for Secondary Schools. 1908.

Duff and Weed. Elements of Physics. 1928.

Dull, C. E. Modern Physics. 1929.

Everett, J. D. Textbook of Physics. 1903.

Fuller, Brownlee, and Baker. Elementary Principles of Physics. 1925.

Gage, A. P. Elements of Physics. 1898.

Gilley, F. M. Principles of Physics. 1901.

Hall and Bergen. A Textbook of Physics. 1893.

Hall, E. H. Descriptive List of Elementary Exercises in Physics (for admission to Harvard College). second revised edition. 1901.

Hoadley, G. E. A Brief Course in Physics. 1900.

Hooke. Philosophic Experiments. 1726.

Ives, J. E. Experiments in Physics(manual). 1912.

Jones, D. E. Heat, Light, and Sound. 1901.

Kelvin and Tait. Elements of Natural Philosophy. 1894.

Millikan and Gale. A First Course in Physics. 1906.

Millikan, Gale, and Pyle. Elements of Physics. 1927.

Stewart, Balfour. Lessons in Elementary Physics. 1875; 1880; 1908.

Stewart and Gee. Elementary Practical Physics. 1894.

Stroud, H. Elementary Practical Physics (manual). 1907.

Wentworth - Hill. A Textbook of Physics. 1898.

Wormell. Natural Philosophy. 1877.

Wright, M. R. Physics. 1893.